THE EFFECTS OF DIET COMPOSITION ON EXERCISE PERFORMANCE IN HIGHLY TRAINED CYCLISTS

by

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By

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ABSTRACT

Background: Traditionally, many highly-trained athletes have consumed a high-carbohydrate diet (HCD) to enhance exercise performance. A more recent trend among some athletes is to consume a ketogenic diet (KD), a low-carbohydrate diet, for better exercise performance. It is not clear whether the traditional HCD results in better exercise performance compared to a KD in highly-trained athletes.

Purpose: To compare the effects of a KD versus a HCD on exercise performance including time to complete a 30 km cycling time-trial, rating of perceived exertion (RPE), and substrate utilization or respiratory exchange ratio (RER).

Methods: Five endurance trained male and female cyclists and triathletes, ages 18-70 years, were asked to consume a KD and a HCD, for 14 days each, in a randomized cross-over design. Measurements were taken at the beginning of the study while on the habitual diet (HD) and at the end of the KD and HCD conditions and included time to complete time-trial, RER, and RPE during a 30-km time trial. The effect of diet condition on time to complete the time-trial, RER, and RPE were assessed by repeated measures analysis.

Results: Time required to complete a 30-km time-trial and RPE were not significantly different for participants between diet conditions. RER was significantly lower in the KD compared to HCD and HD conditions [$F(2, 8) = 73.08$, $p = <.001$, $n^2p = 0.948$].

Conclusion: There was no difference in time to complete the time-trial or RPE by diet condition but a lower RER in the KD condition compared to the other conditions. Future studies with a larger sample size are needed.

CHAPTER 1

INTRODUCTION

There are nearly 62,000 competitive cyclists in the United States; 82% of them being within the age range of 18-65 years old. Of those cyclists, the majority are male with a remaining 16% female population (1). Cycling is a form of exercise that relies on aerobic metabolism, in which the body creates energy by oxidizing mainly fats and carbohydrates as energy substrates.

The energy substrate, carbohydrate undergoes glycolysis to produce pyruvate. Pyruvate proceeds to turn into acetyl CoA and enter the Krebs cycle. The majority of Adenosine Triphosphate (ATP), our bodies high energy molecule, is produced in this pathway at the Electron Transport Chain. Fat, on the other hand, undergoes beta-oxidation and too, produces products that enter the Krebs cycle and continues on to form ATP at the Electron Transport Chain (2).

Energy availability in the body differs between fat and carbohydrates as we have more energy stored in the form of fat (~74,000kcal) than we do in the form of carbohydrates (~2,500kcal). When we utilize these stores, more ATP per molecule of substrate is obtained from fat compared to per molecule of carbohydrate. However, carbohydrate utilization via glycolysis is a shorter process than fat utilization via beta oxidation, making ATP more readily available from the former process. From carbohydrates, per molecule, 2.5 ATP is obtained per second while only 1.5 ATP is yielded per second from fat (3). This is why the body prefers carbohydrate oxidation at higher intensities, due to it needing the fuel at a faster rate. As intensity of exercise increases, the percent energy obtained from fat utilization decreases as carbohydrate utilization increases (4).

This is why traditionally, since the 1960's, it has been thought that a diet high in carbohydrates is necessary to optimize exercise performance. It was discovered then that muscle glycogen depletion was associated with fatigue (5). Glycogen use in working muscles differs at varying intensities. At higher intensity exercise, glycogen stores deplete within sixty minutes, while at lower intensities it takes longer to deplete those stores (6). Among individuals who perform exercise at moderate and heavy exercise intensities, glycogen depletion occurs around 60-90 minutes. The American College of Sports Medicine (ACSM) recommends that athletes, such as trained cyclists, should consume roughly 60% of their daily needs from carbohydrates (7). However, a study done by Volek et al. showed that athletes are more commonly not meeting what is recommended, as evidenced by only getting 55% carbohydrates (5).

Recently, the idea of a ketogenic diet has had an upward trend in popularity, not only among the general population, but with competitive athletes as well. The ketogenic diet is defined as having no more than 5-10% of total energy intake coming from carbohydrate sources (8). This may result in ketosis, showing elevated fat derived ketone bodies and decreased glucose in the blood. Ketosis is a metabolic state in which the body obtains energy from the metabolism of ketone bodies, beta hydroxy butyrate (BHB), acetoacetate, and acetone, specifically (9). As there is a decrease in carbohydrate availability and insulin secretion, there is an increase in free fatty acid (FFA) availability in the blood. The FFA's are then transported from the adipose tissue to the liver. Once FFA's enter the liver ketone bodies are produced as a byproduct of beta oxidation. The major ketone bodies, BHB and acetoacetate, are released into the blood stream and transported to the muscle where they can be used in the Krebs cycle to produce adenosine triphosphate (ATP), energy for the muscle (9). In addition to fat adaptation, the body will produce a higher amount of ketone bodies when in ketosis and therefore result in high amounts of energy availability for one's body to utilize to fuel exercise. This is why today it is questioned whether the traditional high carbohydrate or the newest arise of the ketogenic diet would be more beneficial for exercise performance.

A number of studies have evaluated the regulation of carbohydrate and fat metabolism in relation to exercise intensity. According to a meta-analysis, with five studies, conducted by Holloszy et al., carbohydrate oxidation was more predominant on high carbohydrate diets at higher intensities. On the high-fat diet, at the same high intensities, participants were able to rely mainly on oxidation of fat for energy production (10). This produced the idea that if the body can adapt to using majority of fat at higher intensities, then there would be much more substrate available to fuel exercise and therefore delay fatigue.

Purpose Statement

The purpose of this study was to compare the effects of a ketogenic diet (KD) versus a high-carbohydrate diet (HCD) on exercise performance and physiological responses including time to complete a cycling time-trial, rating of perceived exertion (RPE), and substrate utilization (respiratory exchange ratio (RER)).

Research Question

I. What is the effect of a ketogenic vs. high-carbohydrate diet on performance time to complete a 30-km cycling time-trial in trained cyclists?

II. What is the effect of a ketogenic vs. a high-carbohydrate diet on substrate utilization in trained cyclists?

    a. Respiratory exchange ratio (RER)

Hypothesis

I. It was hypothesized that a high-carbohydrate diet would result in less time to complete a cycling time-trial compared to a ketogenic diet.

II.

a. It was hypothesized that substrate utilization would be primarily carbohydrates during exercise while on high-carbohydrate diet, as evidenced by a significantly higher RER.
b. It was hypothesized that substrate utilization would be primarily fat during exercise while on ketogenic diet, as evidenced by a significantly lower RER.

Significance

The population of cyclists in the U.S. spend a great deal of time and an estimated 6.2 billion dollars on gear, racing, and training (11). This activity is an investment for many and consist of a dedicated group of individuals who strive to improve their performance. Making sure that the nutritional strategies they are utilizing are benefitting and not hindering performance, in both male and females, is of great importance and high demand with these athletic populations.

CHAPTER 2

REVIEW OF LITERATURE

In the past few years, the ketogenic diet has become a widely used diet, as well as a controversial topic of interest in the medical and scientific communities as a dietary intervention treatment for obesity and diabetes (12). Additionally, the athletic community has investigated it for the potential promise as a “super fuel,” for exercise performance (13). Although the diet has been successfully used for treatment of certain health conditions, the long-term impact of the diet, and its use as a performance-enhancing method is still a debated topic. In this literature review, results from studies that have investigated the effect of a ketogenic diet compared to a high-carbohydrate diet on measures of performance will be examined. The review will also identify limitations of the studies.

In this case study, Mujika (14) reported performance outcomes and subjective assessment of a low-carbohydrate, high-fat dietary intervention, over 32 weeks, in a 32 year old male world-class long-distance triathlete with a history gastrointestinal (GI) distress. The subject changed his habitual high-carbohydrate diet to low-carbohydrate, high-fat for 32 weeks. While on the diet he participated in three professional races, but acutely restored carbohydrate availability for pre-event meals and during the race. The subject adhered to the intervention for 95% of the study as assessed by a 7-day weighed dietary record method. Results showed that the participant had his worst-ever half-Ironman performance after 21 weeks, his second worst-ever Ironman performance and suffered the same GI distress (e.g., malabsorption of exogenous CHO, bloating) after 24 weeks and was not able to finish his third race after 32 weeks on the low-carbohydrate, high-fat diet. Within five weeks after going off the low-carbohydrate, high-fat diet he regained his usual performance level. The study was limited by the fact that performance evaluation was based on competition outcomes and the athlete’s subjective assessments as opposed to a controlled study in a laboratory. Also, potential impact of other factors that could affect competition performance cannot be assessed from the available data. Lastly, the study was not randomized and only included one subject.

In a more recent study, Prins et al. (15) tested the hypothesis that the performance of competitive recreational athletes would be impaired during simulated 5 km running time-trials, at >80% VO_{2max}, when on a low-carbohydrate, high-fat compared to a high-carbohydrate, low-fat diet. Seven male competitive recreational distance runners, ages 18 to 45 years, underwent two 42-day experimental conditions (HCLF or LCHF) in a randomized, counterbalanced, crossover design, with a two-week washout period between dietary interventions. Subjects received dietary instructions prior to the beginning of the study. All subjects provided 3-day weighed dietary records (2 weekdays and 1 weekend) for their habitual diet, as well as every week during the study. Macronutrient goals for the low-carbohydrate, high-fat was <50g/day carbohydrate, 75-80% fat, and 15-20% protein. On high-carbohydrate, low-fat, 60-65% carbohydrate, 15-20% protein, and 20% fat were the diet guidelines. Both diets consisted of ad-libitum consumption of foods that allowed for their macronutrients to fall within the given goals. A 5-km running time-trial was performed four times (day 4, 14, 28, and 42) during each dietary intervention. Results indicated that the low-carbohydrate, high-fat diet compared to the high-carbohydrate, low-fat diet resulted in a significantly longer time to complete the first 5 km time-trial but there was no difference in the remaining time-trials. The study was limited by the small number of subjects, all subjects were male, and bioelectrical impedance was used for body composition analysis.

This case study by Webster et al. (16) evaluated the exercise performance of an elite endurance athlete on a low-carbohydrate, high-fat, ketogenic diet compared to a ketogenic diet plus a carbohydrate supplement. The athlete consumed a ketogenic diet for 2 years followed by a ketogenic diet with a carbohydrate supplement for 3 weeks. Performance measures were taken during 3 days of each phase. During the ketogenic + carbohydrate phase, he followed his usual low-carbohydrate, high-fat diet and ingested 60 g of carbohydrate (8% of energy from carbohydrate: two-thirds maltodextrin and one-third fructose) during each of the 8 high-intensity training sessions and performance trials. The high-carbohydrate reintroduction phase compared to the ketogenic phase was associated with significantly lower time to complete a 20 km time-trial. There was no difference between the two phases in a 4-min sprint power and a 100 km time-trial, however, between the two phases. The limitations of this study include there was only one subject, neither athlete nor experimenter were blind to intervention phase, there was only one set of tests conducted in each phase, a potential for order effect, and it was not randomized controlled diet.

Burke at al. (17) evaluated the effects of a high-carbohydrate diet, periodical-high-carbohydrate availability diet and a high-fat diet given over 3-weeks each during a period of intensified training on exercise metabolism and performance of twenty-one world-class male endurance athletes between the ages of 25 and 28 years. Subjects were allowed to select their diet prior to the camp. The high-carbohydrate availability diet consisted of 60–65% of energy from carbohydrate, 15–20% protein, 20% fat. The periodical-carbohydrate availability had the same overall macronutrient composition as high-carbohydrate, but spread differently between and within days according to fuel needs of training as well as an integration of some training sessions with high-carbohydrate availability (high muscle glycogen, carbohydrate feeding during session) and others with low-carbohydrate availability (low pre-exercise glycogen, overnight fasted or delayed post-session refueling; low-carbohydrate, high-fat-75–80% fat, 15–20% protein, < 50g day−1 carbohydrate). Three weeks of intensified training incorporating race walking, resistance training, and cross-training were administered. Immediately before and after the 3-week training, participants completed a 3-day test block that included treadmill test to assess VO_2 peak and economy, 10 km race, and a standardized 25 km long walk to assess exercise performance. Results showed that chronic adaptation to a ketogenic low-carbohydrate high-fat diet impaired exercise economy, the quantity of oxygen required to move at a given speed or generate a specific amount of power and negated the transfer of training-induced increases in VO_2 peak into improved performance of a real-life endurance event in elite athletes. In contrast, training with a diet rich in carbohydrate and which provided either high or periodical-carbohydrate availability around training sessions was associated with improved race outcomes. The high-carbohydrate and periodical-carbohydrate groups completed Race 2 in a significantly faster time than Race 1, showing 6.6% (90% CI: 4.1, 9.1%) and 5.3% (3.4, 7.2%) improvements in performance following the 3-week diet and training intervention, respectively. In the low-carbohydrate high-fat group, completion times between Race 1 and Race 2 were not different. Limitations of the study were that subjects were not randomized to the diet, rather assigned based on preference, and all were male elite athletes.

McSwiney et al. (18) investigated performance effects of consuming a low-carbohydrate high-fat ketogenic diet, over 12-week, in competitive endurance athletes. They tested the hypothesis that keto-adapted (describes the physiological adaptations an individual goes through following consumption of a low-carbohydrate high-fat ketogenic diet) athletes could maintain/improve performance on the low-carbohydrate high-fat ketogenic diet. This non-randomized control trial included twenty male endurance trained athletes between the ages of 18-40 years. The participants self-elected into either a high-carbohydrate group or a low-carbohydrate high-fat ketogenic diet group and performed the same training intervention throughout. Prior to and following the 12-weeks of diet and training, subjects had their body composition assessed, completed a 100-km time-trial, six-second (SS) sprint, and a critical power test (CPT). The dietary intervention consisted of pre-intervention nutritional counseling on the diet they had chosen and the macronutrient goals for each diet were as follows: high-carbohydrate 65% carbohydrate, 20% fat and 14% protein, or low-carbohydrate high-fat ketogenic diet >75% fat, 10-15% protein and <50g/day carbohydrate. Three-day weighed dietary records (2 weekdays and 1 weekend day) were obtained at baseline as well as at week 12 of the experiment. During post-intervention testing the high-carbohydrate group consumed 30-60 g/h carbohydrate, while low-carbohydrate high-fat ketogenic diet group only consumed water and electrolytes. Results showed the time to completion of the time-trial tended to be longer in the low-carbohydrate high-fat ketogenic diet compared to the high-carbohydrate group. Also, fat oxidation was significantly greater throughout the 100 km time-trial in the low-carbohydrate high-fat ketogenic diet group. Limitations of this study include that subjects were not randomly assigned to groups and only male participants were included.

Bykowska (19) tested the hypothesis that adaptation to high-fat diet followed by short term high-carbohydrate intake will improve repetitive performance using a treadmill exercise test simulating a soccer game. Nine healthy, trained males between the ages of 18-45 were included in this randomized crossover single blinded design. The dietary interventions included : 1) a high-carbohydrate diet that consisted of a seven day protocol involving consumption of 65% total daily energy from carbohydrate, and 21% from fat and 2) a fat-adaptation diet consisting of the first five days being a high fat diet with 21% energy from carbohydrate, and 58% fat followed by two days high in carbohydrates; 64% energy from carbohydrate and 24% fat. Diets were isocaloric and protein intake was 1.2 g/kg/day. Diets were chosen in random sequence and blinded for the lab staff which performed study visits. On day 7, subjects performed an interval treadmill test (protocol developed by Bangsbo et al. (20)) mimicking a soccer game with the distance covered ranging from 8-13 km. Results indicated a significant decrease in total distance to exhaustion after the fat-adaptation diet ($p < 0.05$) in comparison with the high-carbohydrate diet in which total distance to exhaustion was significantly longer. Limitations included possibility of test familiarity on consecutive test days and that subjects were not fully recovered from the day one test for the collection of day two tests.

In this randomized, cross over study, Stepto et al. (21) determined the effect of short term (3 day) dietary fat adaptation on high intensity exercise training. The study included seven, well-trained competitive male cyclists or triathletes with a history of regular exercise training, ages of 18-30, and with a VO_2 peak of 4.5-5.5 L/min, and peak aerobic power output of 364-444 W. Subjects consumed a standardized diet on day-0 followed by either 3-days of high-carbohydrate (11 g/kgBW/d carbohydrate, 1 g/kgBW/d fat), or an isoenergetic high-fat (2.6 g/kg/d carbohydrate, 4.6 g/kg/d fat) diet separated by an 18-day wash out period. On the 1st and 4th day of each treatment, subjects completed a standardized laboratory training session consisting of a 20-min warm-up at 65% of VO_2 peak (209-255 W) immediately followed by 8 x 5 min work bouts at 86 +/- 2% of VO_2 peak (291-355 W) with 60-s recovery. Ratings of perceived exertion during nonlaboratory training were greater for both cycling ($p < 0.05$) and all "other training" ($p < 0.01$) during the high-fat diet compared with the high-carbohydrate diet. The limitations of the current study include the small number of participants whom were all highly trained and male, and testing VO_{2max} values alone fail to provide valid information regarding any change in training status of an individual.

Rowlands et al. (22) compared the effects of high-fat and high-carbohydrate dietary conditions on metabolism and short- and ultra-endurance cycling performance. Seven male cyclists, between the age of 22-32, all whom had a VO_{2max} of 65-79 mL/kg/min and peak power of 337-419 W were included in the study. In this crossover study, each subject underwent a 2-week adaptation to each of the following 3 diets: 14-days of high-carbohydrate diet with 70% energy from carbohydrate, 16% energy from fat, and 14% energy from protein; 14-days of high-fat with 66% energy from fat, 20% energy from protein, and 15% energy from carbohydrate; 11.5-days of high-fat diet followed by 2.5-days of carbohydrate-loading. The conditions included a pre-exercise meal of the same composition as the preceding diet. Each diet condition was preceded by a 2-week standardizing normal diet. Exercise performance was assessed over approximately a 5-hour period and comprised a 15-minute trial, an incremental test to measure the peak fat-oxidation rate, and a 100-km trial. Sports bars and a 5% carbohydrate solution were ingested during the tests. Results indicated that the diets had no statistically significant effect on 15-minute performance. In the 100-km time-trial, the high-fat and the high-fat with carbohydrate-loading conditions attenuated the decline in power output observed in the high-carbohydrate condition (p =.03 to.07). Overall, for every 10% energy increase in dietary fat, 100-km mean power increased by 2% (-0.0% to 4%, p =.06). There could be a distance and intensity related effect as they were working at a lower intensity and would be more efficient. Limitations of this study included the small sample size and that the subjects were all young male.

Lambert et al. (23) investigated the effects of 2 weeks of either a high-fat or high-carbohydrate diet on exercise performance in trained cyclists during consecutive periods of cycle exercise. Five endurance-trained male cyclists, ages 20-24, all cycling 100-200 km each week, with a mean VO_{2max} of 4.2 L/min, were included in this randomized cross-over study. Prior to performance trials, subjects were randomly assigned to two 2-week periods of either a high-fat (67% energy from fat, 7% energy from carbohydrate, 25% energy from protein) or a high-carbohydrate (74% energy from carbohydrate, 12% energy from fat, 14% energy from protein) diet. All performance trials were conducted in the morning, after an overnight fast. These performance assessments included a Wingate test of muscle power, cycle exercise to exhaustion at 85% of peak power output [90% maximal oxygen uptake (VO_{2max}), high-intensity exercise] and 50% of peak power output [60% VO_{2max}, moderate-intensity exercise]. Results indicated that exercise time to exhaustion during moderate-intensity exercise was significantly longer after the high-fat diet in comparison to the high-carbohydrate diet [79.7 (SEM 7.6) vs 42.5 (SEM 6.8) min, high-fat vs high-carbohydrate, $p < 0.01$]. These results would suggest that 2 weeks of adaptation to a high-fat diet would result in an enhanced resistance to fatigue and a significant sparing of endogenous carbohydrate during low to moderate intensity exercise in a relatively glycogen-depleted state and unimpaired performance during high intensity exercise. A limitation of the study included that the high-fat diet was also relatively higher in protein content, when comparing to the equal energy high-carbohydrate diet. The study also lacks generalizability due to the small number of subjects and only consisting of endurance trained, male individuals.

Summarized findings

After reviewing the literature on the effects of a low-carbohydrate high-fat diet vs. high-carbohydrate low-fat diet on exercise performance, some trends in results have been observed, as well as limitations that could be improved in future studies. In studies that examined changes in time to complete certain exercise bouts, all indicated that times decreased significantly when subjects were consuming a high-carbohydrate low-fat diet compared to when consuming the low-carbohydrate high-fat, except for one (18). Another performance measure that was improved when subjects were on high-carbohydrate low-fat was time to exhaustion or rating of perceived exhaustion. More distance was covered and/or subjects were able to last longer during an exercise bout when on a high-carbohydrate, low-fat diet (19,21). The only study that said otherwise was

Lambert et al. who found that exercise time to exhaustion during subsequent moderate intensity exercise was significantly longer after the high-fat diet (23).

Overall limitations in these studies were that all included younger male subjects. This decreases the generalizability to other populations such as women and older individuals. The sample size in all but two (17,18) studies were under 10. Not all of the studies were randomly controlled . Another limitation was that in some studies the diet adaptation period was not long enough to contribute its performance results to the diet (20). In one study the protein intake was different between the two diets and so it is not clear whether the performance outcomes were due to differences in protein intake of differences in fat and carbohydrate intake between the two (22). Some diets were not randomly assigned to the subjects (15–17). Additionally, bioelectrical impedance was used for body composition analysis (23). In one case study, evaluation of the low-carbohydrate high-fat intervention relied mostly on competition outcomes and the athlete's subjective assessments (13). Lastly, there needs to be optimal recovery time between test days so that it does not affect outcomes, unlike in one study in which the subjects were not fully recovered from the day one test for the collection of day two tests (18).

CHAPTER 3

MATERIALS AND METHODS

Participants

Five endurance trained male and female cyclists and triathletes, ages 18-70, were recruited for this study from the TCU and cycling and triathlon communities in the DFW metroplex via emails, newsletters, social media, fliers, classroom announcements, and word of mouth. Participants were considered highly trained if they cycled $\geq$100-150 km per week for the last year and a VO_{2max} above the 80th percentile for their sex and age according to guidelines put forth by the ACSM (7). We adjusted these guidelines based on the fact that they were established in the treadmill, but studies show that even trained cyclists and triathletes reach a lower "VO_{2max}" on the cycle ergometer compared with the treadmill (24).

Exclusion criteria included any self-reported use of medications or supplements to lose weight, following a ketogenic (<5-10% or less of total energy intake from carbohydrates), extremely high-carbohydrate (65-75% of total energy intake from carbohydrate), or weight loss diet, nicotine use, heavy alcohol consumption (>14 drinks/week for males; >7 drinks/week for females). Potential participants were excluded if they self-reported any food allergy, presence of diabetes, heart disease, stroke, or liver, kidney, or untreated thyroid disease, anemia, eating disorders, uncontrolled hypertension, or pulmonary, orthopedic, arthritis, or musculoskeletal problems that prevent exercise. Potential participants were also excluded if they have undergone surgery that affects swallowing or digestion or are claustrophobic. Further, women of childbearing age who are not taking oral contraceptives were excluded. Date of last menstrual cycle was recorded.

The University's Institutional Review Board approved the study before beginning recruiting participants. All participants read and signed the informed consent prior to taking part in the study. Data Collection took place in the Metabolic, Exercise Physiology, and Obesity Prevention Laboratories on the TCU campus.

Experimental Design

Using a randomized cross-over trial design, the effects of a high-fat low-carbohydrate ketogenic diet (KD) versus a high-carbohydrate low-fat diet (HCD) on exercise performance was studied. Participants served as their own control. Each participant went through both dietary phases. Participants were instructed to report to the Metabolic/Exercise Physiology/Obesity Preventions Laboratories for two screening visits and 5 additional visits to monitor adherence to the ketogenic and high-carbohydrate diets and for data collection.

Dietary Interventions

Participants completed dietary records for 3 days (2 weekdays and 1 weekend day) during their habitual diet (HD) leading up to Experimental Trial 1 (ET 1). Following ET 1, they adhered to two diets in a random order for 14 days each: (i) ketogenic diet (<10% energy from carbohydrates; 75-85% from fat, 15% from protein) and a (ii) high-carbohydrate (>65% energy from carbohydrate, <20% from fat, 15% from protein). Protein intake for each diet was held constant at 15% of total daily energy needs for both the KD and HCD.

While instructing the participants on the KD, recommendations included avoiding breads, starchy vegetables, grains, high-carbohydrate fruits, and sugary foods and substituting them for higher fatty items such as fatty meat cuts, whole eggs, and adding olive oil, butter, avocados, nuts, and heavy cream. Appendix A shows an example of days on this meal plan based on a 2,500-kcal diet. Recipes and additional suggestions related to this diet are presented in the appendix.

While instructing participants on the HCD, recommendations included consuming lower fat and protein sourced foods in order to reach the high percentage of intake from carbohydrates. This was done by increasing high amounts of breads, grains, starches, fruits and added sugars. The registered dietitian would suggest adding jams, honey, sugar, fruits, fat-free sauces and other highly concentrated sugar sources. Appendix B shows an example of days on this meal plan based on a 2,500-kcal diet. Recipes and additional suggestions related to this diet are presented in the appendix.

The Registered Dietitian on staff supplied all participants with example meal plans and recipe books corresponding with each diet, instructed on how to follow each diet, and completed daily check-ins to ensure compliance. Dietary compliance was defined as meeting macronutrient percentages on at least 80% of days for the KD and the HCD. Daily check-ins using mobile applications (WhatsApp, WhatsApp Inc., Mountain View, CA; Nutritio, NATURALPIXEL SRL., București, Romania) with the investigators included written food records, photos of the participants' recorded food, participants' weight, urinary ketone strips while on the KD, and any other pertinent information regarding their diet. The investigators provided feedback to each participant on a regular basis to ensure that they were following the dietary instructions and weight was maintained throughout the duration of the study. Weight maintenance was considered weight loss or gain of no more than 5% initial body weight. However, due to recruiting restraints, participants were not excluded if weight changes crossed this threshold; rather, weight changes were recorded throughout the study. Adherence to the KD was also assessed through urine and blood ketone concentrations.

Test meals and water intake

Liquid test meals contained a total energy amount of 60% of the participants' RMR (kcals/day) and contained a standard American composition (control diet; 31.4% fat, 53.4% carbohydrate, 15.2% protein) at baseline, a ketogenic composition (75.10% fat, 9.5% carbohydrate, 15.4% protein) after 14 days on the ketogenic diet, and a high-carbohydrate composition (15.7% fat, 69.1% carbohydrate, 15.2% protein) after 14 days on the high-carbohydrate diet. Volumes and caloric content of the test meals were kept constant across conditions.

The standard American meal consisted of honey, honey yogurt, whole milk, frozen strawberries, frozen bananas, and MCT oil powder. The ketogenic shake consisted of pecan butter, heavy whipping cream, unsweetened cashew milk, whole milk Greek yogurt, avocado, MCT oil powder, whey protein powder, and water. The high-carbohydrate shake consisted of honey, dates, whole milk, plain whole milk yogurt, frozen bananas, whey protein, Nesquik strawberry powder, and water. Water was added to the liquid test meals in order to keep weight constant across each diet condition. Nutrient breakdown of each test meal is shown in **Table 1**. Test meal recipes are available at https://osf.io/ujx6e/.

Table 1. Nutrient breakdown of each test meal

Composition	HD	HCD	KD
Kilocalories	519	518	519
Carbohydrate (g)	71.0	94.4	12.9
Fat (g)	18.6	9.5	45.2
Protein (g)	20.3	20.7	20.8
Dietary fiber (g)	6.0	4.6	5.5
Weight (g)	530	530	530
Carbohydrate (% energy)	53.4%	69.1%	9.5%
Fat Intake (% energy)	31.4%	15.7%	75.1%
Protein Intake (% energy)	15.2%	15.2%	15.4%

HD= Habitual diet; HCD= High-carbohydrate diet; KD= Ketogenic diet

Physical activity

Participants were instructed to keep their physical activity levels stable throughout the study. Exercise logs and activity monitors were utilized to track the physical activity levels.

Measurements

Anthropometry.

Weight was assessed in cycling gear, without shoes, using a digital scale (SECA, Chino, California). Height was measured without shoes using a calibrated stadiometer. Waist and hip circumferences were also measured with a standard tape measure.

Air displacement plethysmography (ADP).

ADP uses the relationship between pressure and volume to derive the body volume of a participant seated inside a fiberglass chamber (25). For body composition measurements, participants were required to wear a bathing or spandex suit with all hair collected into a swim cap. Participants were also required to wear nose clips for measurements of thoracic lung volumes. For measurements of thoracic lung volume participants were instructed to place their lips around a breathing tube and breathe according the cadence displayed on the software interface until measurements were complete. Assessments were conducted in duplicate and averaged. Calibration of the BodPod was conducted prior to each measurement according to manufacturer guidelines.

Exercise Equipment.

To ensure familiarity with the exercise equipment and to avoid learning effects across trials, participants were allowed to complete all testing on their personal bicycles mounted to the CompuTrainer ergometer (RacerMate, Seattle, WA), which has previously been shown to be reliable in time-trial tasks similar to the study (26). Calibration of the ergometer was completed before each exercise task according to manufacturer's recommendations, and tire pressure was standardized for each trial according to tire and wheel manufacturer guidelines. Participants were asked to remove devices from their bicycles or deactivate any devices that could give them feedback on their exercise performance, such as power meters and cycle computers.

$\dot{V}$O2max testing.

For the 24 hours leading up to testing, participants were asked to refrain from all exercise. For the initial incremental maximal exercise test, participants warmed up for 5 minutes at a self-selected intensity. Thereafter, participants began the incremental test at a load of 50-100 watts (W). Exercise intensity increased by 25 W per minute until volitional exhaustion. Oxygen uptake ($\dot{V}O_2$) was continuously monitored using a TrueOne 2400 metabolic cart (Parvo Medics, Sandy, UT, USA) and heart rate was collected throughout the test using a Polar H7 heart rate monitor (Polar Inc., Lake Success, NY). $\dot{V}O_2max$ was defined as the highest 30-second $\dot{V}O_2$ value obtained during the test. To ensure validity of the $\dot{V}O_2max$ measurement, participants performed a validation bout at 110% of their maximal power (Wmax) achieved in the initial test following at least 10 min rest as described by Poole & Jones (27). Wmax was calculated as described by Hawley & Noakes (28):

$$Wmax = Wfinal + (t60 \times 25)$$

Following a 2-minute warmup at 100 W, participants performed a steady work rate test that achieved exhaustion within 3-6 minutes. If the greatest $\dot{V}O_2$ measured during this validation test did not exceed the $\dot{V}O_2max$ measured during the incremental test, considering a possible ~3% measurement error based on the equipment used, the achievement of a plateau was accepted. If the $\dot{V}O_2$ achieved during validation exceeded that measured during the incremental test, a new incremental test was performed on a separate day.

Performance Assessment.

Participants completed a simulated 30-km time-trial 180 minutes following ingestion of the test meal. Participants were allowed to change into their preferred clothing prior to performance testing. With their personal bicycle mounted to a CompuTrainer cycle ergometer (RacerMate, Seattle, WA) and tire pressures according to tire and wheel manufacturers' guidelines, participants performed a 10-minute warm up followed by calibration of the press-on force of the load generator as per CompuTrainer manufacturer's guidelines. Participants then began the 30-km time-trial on a virtual course in the RacerMate One software (RacerMate). A copy of the course file can be found at https://osf.io/ujx6e/. Participants were instructed to complete the time-trial as quickly as possible and verbal communication and encouragement was provided throughout the trial. Participants were allowed ad libitum water consumption during the initial performance assessment. Water intake was measured using a graduated cylinder during the initial time-trial and repeated in subsequent trials. Participants' heart rate was monitored continuously using a Polar H7 heart rate sensor and chest strap (Polar Electro Oy, Kempele, Finland). Respiratory gas measurements and ratings of perceived exertion (RPE) on 6-20 Borg Scale was collected at 3 km and every 6 km thereafter (3km, 9km, 15km, 21km, 27km). Capillary blood draws for BHB and muscle ultrasound images were obtained immediately before and after the time-trial.

Respiratory gas analysis.

Respiratory gas measurements were collected using an open circuit automated gas analysis system (TrueOne2400, Parvo Medics, Sandy, UT). Participants breathed through a two-way valve (Hans Rudolph, Shawnee, KS) attached to a 7450 Series Silicone V2^{TM} Oro-Nasal Mask (Hans Rudolph) for three minutes at each collection time point. Averages of the full three minutes of gas measurements at each time point were reported.

Resting metabolic rate.

RMR was measured by indirect calorimetry using the TrueOne® 2400 (ParvoMedics, Sandy, UT, USA) indirect calorimeter with a ventilated hood system. Following a 12hr overnight fast from food, supplements, and medication and a 24hr abstinence from exercise, participants were placed in a ventilated hood system in a climate-controlled room for 30 min to collect respiratory gases that allowed for the measurement of the energy required during rest. The first 10 minutes of the 30 min period were used to allow the participants to achieve resting status and only 20 minutes of expired air was used for analysis. During resting energy expenditure measurements participants were instructed to remain motionless in the supine position without sleeping while respiratory gases were collected. During the ET day measurements, participants were allowed to put in headphones to watch television from a pre-selected list developed to limit excitatory responses. Calibration of the metabolic cart for gas and flow was conducted prior to each measurement according to manufacturer guidelines.

Dietary Intake Assessment

Dietary intake was assessed using a 3-day (2 weekdays and 1 weekend day) dietary record. The participants were asked to keep a detailed record of all the foods and drinks consumed. They were instructed to pick days that represented their usual eating patterns while on each diet, and record all food and drink consumed, including exact portion sizes, second helpings, leftovers, recipes used, and processed foods consumed at each eating occasion on those days. Investigators contacted participants and asked them to supply pictures of foods when able, in order for investigators to clarify the food preparation methods, amounts consumed, and possible missing foods. This is a validated measure (29). All dietary data was analyzed using the Food Processor Nutrition Analysis Software (ESHA, Salem, OR).

Physical Activity Assessment

Physical activity level was monitored by self-report and wearing an accelerometer (ActiGraph GT9X Link; Actigraph Inc., Pensacola, FL) at the waist. The accelerometers were collected and redistributed on visits 4 and 6 to allow for data synchronization and recharging. Participants were asked to keep a written training log to document exercise training volumes and intensities during the study. Participants noted the distance (miles), time (minute) and perceived exertion (1-10 scale) for each training session to allow for calculation of session ratings of perceived exertion (sRPE). SRPE was calculated by multiplying the session time in minutes by the reported RPE for each training session. The accelerometer data and training logs were used to provide regular feedback to the participants to ensure physical activity remains stable. Participants were instructed to wear them on their right hip using their own belts or a provided waistband.

Assessment of Blood and Urine Ketone Levels

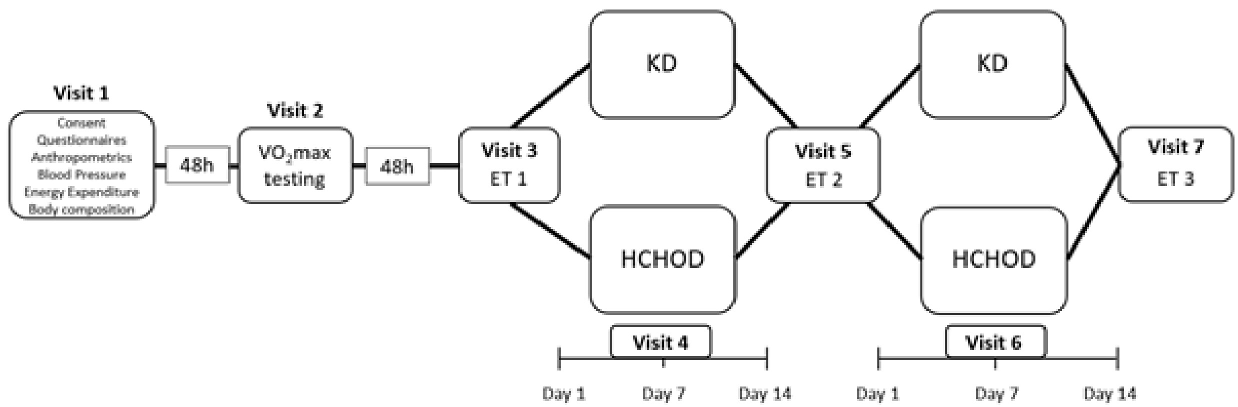
Beta hydroxybutyrate (BHB) concentration in capillary blood was assessed using a KETO-MOJO TD-4279 Blood Ketone and Glucose Testing meter (KETO-MOJO, Auburn, CA). Adhering to the ketogenic diet was considered having an average capillary BHB concentration of ≥0.5mmols. Participants were also provided with urinary ketone test strips (VALI, CA) to measure urinary ketone bodies during the KD period (Misra & Oliver, 2015).

Study Protocol

Participant eligibility was determined during Visits 1 and 2. Visits 3, 5, and 7 were the experimental trials, where participants ingested a test meal, underwent resting measures for 180 minutes, and performed a 30-km cycling time-trial. Visit 3 examined these variables following the participants' habitual diet. Visits 5 and 7 followed 14 days each of a KD and an HCD assigned in random order. Visits 4 and 6 were check-in visits on day 7 of each diet to verify diet compliance.

Diet order was randomized employing block randomization in the blockrand package (30) in R (31) . The syntax for block randomization can be found at https://osf.io/5fd3n/. A diagram showing the experimental design is presented in **Figure 1.**

Figure 1. Experimental Design.



ET = Experimental Trial; KD = ketogenic diet (<5-10% of total energy intake from carbohydrates); HCHOD= high carbohydrate diet (65-75% of total energy intake from carbohydrates); VO$_2$max = maximal oxygen consumption

Screening

Visit 1.

Following a 12-hour overnight fast, participants reported to the Obesity Prevention Lab at the Department of Nutritional Sciences for Visit 1. During this visit, participants signed an IRB-approved informed consent and filled out demographic, behavioral, and health questionnaires. Height, weight, waist and hip circumference, body composition, RMR, and blood pressure was also measured. Body composition was assessed by ADP with measured thoracic lung volume (BodPod™, Life Measurement Inc., Concord, CA). Following body composition and anthropometric measurements, RMR was measured by indirect calorimetry using the TrueOne®

2400 (ParvoMedics, Sandy, UT, USA) indirect calorimeter with a ventilated hood system. BP was measured in duplicate while supine using an automated sphygmomanometer (32).

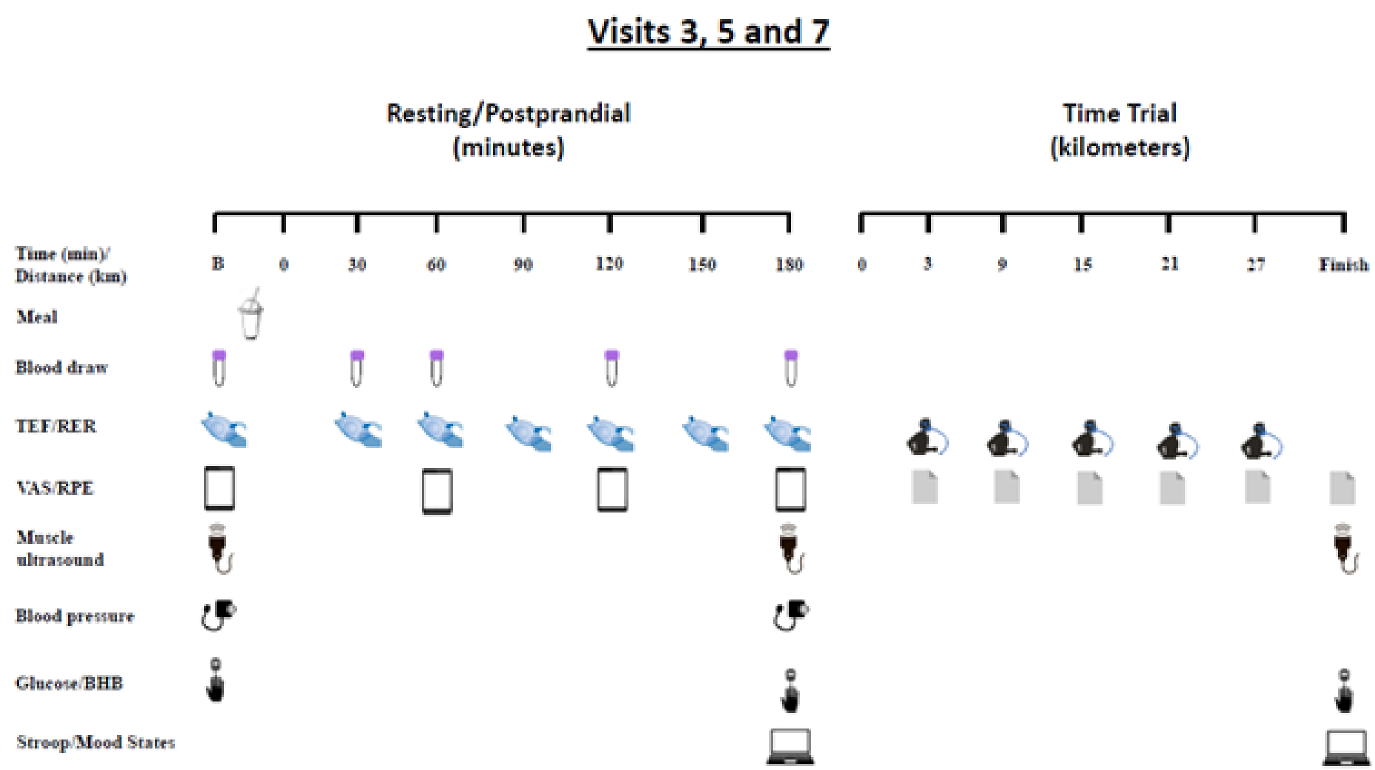
Visit 2.

At Visit 2, participants underwent testing of $\dot{V}O_2max$ in the Exercise Physiology Lab at the Department of Kinesiology using a CompuTrainer ergometer (RacerMate, Seattle, WA). Participants were instructed to refrain from any exercise from 0-24 hours leading up to $\dot{V}O_2max$ testing and to only perform light or moderate exercise 24-48 hours leading up to testing.

Experimental Trials (Visits 3,5, and 7)

A diagram showing all measures performed during each experimental trial is presented in **Figure 2.**

Figure 2. Experimental trial measures and time points.



TEF = Thermic Effect of Food; RER = Respiratory Exchange Ratio; VAS = Visual Analogue Scale (appetite); RPE = Rating of Perceived Exertion; BHB = beta hydroxybutyrate

At baseline (Visit 3) and immediately after the end of each 14-day diet condition (visits 5 and 7), the participants came to the Metabolic and Exercise Physiology Labs for measurement of fasting and postprandial (after a meal) energy expenditure or thermic effect of food (TEF), insulin, glucose, muscle glycogen and performance. From 48-24 hours prior to each experimental trial, participants were instructed to only perform light or moderate exercise. For the 24 hours leading up to testing, participants were asked to refrain from all exercise. Additionally, they were asked to abstain from all food, supplements, and medication during a 12-hour overnight fast. Upon arrival, height, weight, waist and hip circumference, BP, measurements of capillary blood for BHB concentration, and an ultrasound assessment of the right and left rectus femoris (RF) were collected. During each of the three days, following resting measures, blood samples (15 mL or 3 teaspoons at each measurement time point) and self-reported appetite ratings (see questionnaire on appetite ratings in the Appendix) were collected in the fasting state and at 30, 60, 120, and 180 minutes after the meal began, as well as immediately following exercise. Energy expenditure was also measured by a ventilated hood system for 30 min in the fasting state and for 180 min after the meal began. The meals (containing 60% of RER) were provided by the investigators and simulated a traditional American meal at baseline (control diet), a ketogenic meal after the 2 weeks on the ketogenic diet (<5-10% energy from carbohydrate), and a high-carbohydrate (65-75% energy from carbohydrate) meal after the 2 weeks on the high-carbohydrate diet. All test meals were given in liquid form. To prevent dehydration, the participants were provided with 4 ounces of water at 60 and 120 minutes each and 8 oz at 180 minutes during the postprandial phase. Once blood draws and energy expenditure measurements were completed, the participants underwent the performance assessment described above. Participants were allowed ad libitum water consumption during the performance assessment.

Check-In (Visits 4 and 6)

Visits 4 and 6 were check-in visits to verify diet compliance using capillary blood measurements (finger prick) for ketone bodies and glucose. Maintenance of physical activity levels were checked using data from accelerometer and questionnaire.

Participants were also provided with urinary ketone test strips (VALI, CA) to measure urinary ketone bodies during the KD period (Misra & Oliver, 2015). Participants were instructed to use the provided test strips to analyze their urine daily according to manufacturer guidelines. Participants were asked to obtain a photo of the test strip and send it to the investigator immediately after measurement. Ketosis via urinary ketone strips was interpreted as meeting the minimum strip color corresponding with the optimal ketone concentration for ketosis as specified by the manufacturer (i.e. the color of the strips that corresponds with ≥ 0.5mmols).

During the participants habitual diet, seven days into each dietary condition, and at baseline during each experimental trial, participants provided capillary blood samples to measure BHB concentration using a KETO-MOJO TD-4279 Blood Ketone and Glucose Testing meter (KETO-MOJO, Auburn, CA). Adhering to the ketogenic diet was considered having an average capillary BHB concentration of ≥0.5mmols.

Statistical Analysis

Primary analysis.

The primary outcome variable, time to completion (TTC) in the 30-km time-trial was analyzed using a repeated measures analysis of variance (RM-ANOVA) in Jamovi (Version 1.2, Newcastle, New South Wales, AUS). *Post hoc* analysis was performed using a Holm-Bonferroni correction. Participants with missing data in the primary outcome variable were excluded from the primary analysis.

Exploratory analyses.

Exploratory variables (RER, RPE) analyzed using 3x5 (condition x time) RM-ANOVA's using Jamovi (Version 1.2, Newcastle, New South Wales, AUS). While prior research would allow the generation of directional hypotheses regarding RER and RPE we treated them as exploratory, since we did not power the study to these variables. Missing data for exploratory analyses were imputed using mean substitution.

Control variables.

Dietary intake, body weight, physical activity, and capillary BHB were treated as control variables. Dietary intake, body weight and fluid intake were analyzed using RM-ANOVA's using Jamovi (Version 1.2, Newcastle, New South Wales, AUS). sRPE and training volume were analyzed using paired sample t-tests using Jamovi (Version 1.2, Newcastle, New South Wales, AUS). Capillary BHB was analyzed using 3x3 RM-ANOVA's using Jamovi (Version 1.2, Newcastle, New South Wales, AUS). Potential mean differences in the RMANOVA analysis were analyzed using a Holm-Bonferroni *post hoc* test.

Outliers and assumption checks

Observations >2.5 standard deviations from the sample mean were considered outliers and excluded from all variables. Normality and homoscedasticity were assessed using the Shapiro-Wilk test and visual inspection of residual plots. All data were approximately normally distributed.

CHAPTER 3

RESULTS

Participant Characteristics

Four female and one male cyclist participated in the study. Anthropometric, demographic, and cycling data on the five highly trained cyclists are displayed in **Table 2**. Additionally, all participants reported no smoking, no diagnosed medical or current health conditions, no current injuries, did not adhere to any specific dietary programs, and did not track calories or macronutrients prior to the study. None of them utilized performance enhancing drugs, and only one individual reported use of prescription medication for attention deficit hyperactive disorder. Three out of the five participants utilized supplements including intra-workout aids, vitamins and minerals, and protein and carbohydrate supplements. All participants had competed in sanctioned cycling events and included resistance training in their weekly routine. All but two participants engaged in extra endurance exercise (i.e. swimming/running), and all but one participated in additional recreational activity (i.e. yoga) weekly.

Table 2. Participant Characteristics

Variables	Total (n=5)	Males (n=1)	Females (n=4)
Age (year)	33.4±9.0	27.0	35±9.5
Ethnicity			
• Non-Hispanic	100%	100%	100%
Race			
• White	100%	100%	100%
Height (cm)	170.0±8.1	184.0	167.0±5.3
Weight (kg)	63.4±13.6	84.1	58.2±8.3
Body mass index (kg/m^2)	21.7±2.5	24.8	20.8±2.0
Percent body fat (%)	20.3±4.4	16.0	21.4±4.2
RMR (kcals/day)	1531±261	1951	1426±132
VO_{2max} (ml/kg/min)	47.5±7.2	52.0	46.3±7.8
Cycling Experience (Years)	4.3±4.0	10.0	2.9±2.8
Cycling Miles/Week	136±46	143	110±50

RMR, resting metabolic rate; VO_{2max}, maximal oxygen consumption; The data are presented as percentages for categorical variables and means and standard deviations for continuous variables.

Dietary Intake, Marker (Beta-hydroxybutyrate) of Ketosis, Body Weight, and Physical Activity Exertion during the Study

Table 3. outlines the dietary intake and marker (Beta-hydroxybutyrate) of ketosis of the participants during the four-week diet prescription period. No statistically significant differences [F(2,8) =1.14, p = 0.368, n^2p = 0.221] were found in average energy intake between diet conditions. There was a significant difference in percent energy from carbohydrate intake [F(2,8) = 211, p = <.001, n^2p = 0.981] and fat intake [F(2,8) = 75.1, p = <.001, n^2p = 0.949] between all diet conditions. During the KD phase, percent energy from protein intake was significantly higher [F(2,8) = 19.9, p = <.001, n^2p = 0.832] than the other two diet conditions.

Overall, there was a significant condition by time interaction [F(4,16) = 3.67, p = 0.026, n^2p = 0.479] of BHB (beta -hydroxybutyrate) measures. After the KD condition, BHB levels were significantly greater [t(11.6) = 4.657, p = 0.015] at the fasting timepoint than during HCD. Also, KD BHB was significantly greater at both the postprandial and post exercise timepoints compared to all other diets.

Table 3. Dietary Intake and Marker (Beta-hydroxybutyrate) of Ketosis During the Study

Variables	HD (n=5)	KD (n=5)	HCD (n=5)	p-value
Energy Intake (kcal)	2135±622	2509±509	2372±721	0.37
Carbohydrate (% energy)	45.8±7.3	7.7±2.0	66.6±3.3	<.001*
Fat Intake (% energy)	37.6±6.7	66.1±3.8	18.4±4.7	<.001*
Protein Intake (% energy)	16.8±4.0	26.0±3.2	14.4±3.5	<.001**
BHB (mmol/L)				0.026†
• **Fasting**	0.29±0.16	1.09±0.63††	0.11±0.20	
• **Postprandial (180 min)**	0.15±0.11	1.12±0.47†††	0.01±0.02	
• **Post exercise**	0.43±0.21	1.66±0.60†††	0.14±0.15	

HD, habitual diet; KD, ketogenic diet; HCD, high carbohydrate diet; BHB, beta-hydroxybutyrate; The p-value was determined by repeated measures ANOVA. *All diets were significantly different from each other; **KD was significantly higher in protein intake than the other two diet conditions. †Significant condition by time interaction; ††KD was significantly greater than HCD; †††KD was significantly greater compared to other diets.

Table 4. includes body weight and physical activity control variables throughout the study. Participants weight was significantly lower [$F(2,8) = 18.2$, $p = 0.001$, $n^2p = 0.820$] during the KD condition compared to the other two conditions. Self-reported sRPE revealed no significant differences [$t(4) = -1.49$, $p = 0.211$, Cohen's $d = -0.665$] between the KD and HCD conditions. Additionally, total training volume did not differ [$t(4) = 0.665$, $p = 0.542$, Cohen's $d = 0.298$] between the KD and HCD conditions.

On each of the three experimental trial days, during the 30 km time-trial, fluid intake was not significantly different [$F(2,8) = 1.78$, $p = 0.23$, $n^2p = 0.308$] between conditions.

Table 4. Body Weight and Physical Activity Exertion During the Study

Variables	HD (n=5)	KD (n=5)	HCD (n=5)	p-value
Weight (kg)	63.4±13.1	61.4±12.7	63.5±13.4	0.001***
Training volume (miles)	N/A	239±84	261±90	0.542
SRPE	N/A	448±277	594±248	0.21
Fluid intake during time-trial (mL)	371±77	316±131	331±108	0.23

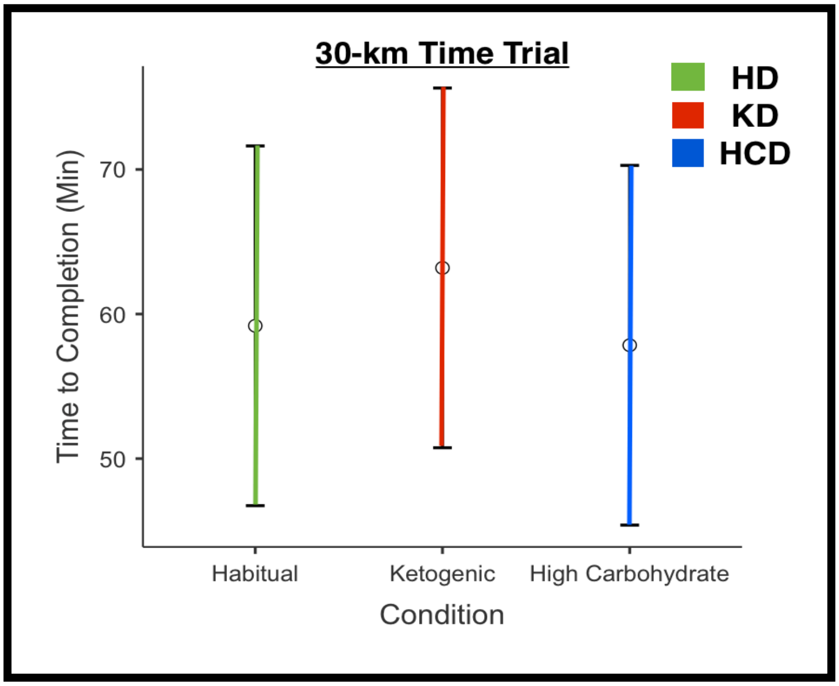
HD, habitual diet; KD, ketogenic diet; HCD, high carbohydrate diet; SRPE, training volume multiplied by ratings of perceived exertion. The p-value was determined by repeated measures ANOVA for weight and fluid intake and using paired t-test for SRPE. ***Weight was significantly lower in the KD compared to the other two diet conditions.

Performance and Fuel Utilization

Time-trial

The effect of the diets on time to complete the 30-km time-trial is shown in **Figure 3.** Time required to complete the 30-km time-trial was not significantly different for participants between diet conditions [$F(2, 8) = 3.96$, $p = 0.064$, $n^2p = 0.498$]. Time-trial duration tended to be faster during the high-carbohydrate condition compared to the ketogenic condition. To ensure that there were no learning effects across the diets, we also compared time-trials in order of completion. There was no significant [$F(2,8) = 0.163$, $p = 0.852$, $n^2p = 0.039$] difference in time-trial performance.

Figure 3.

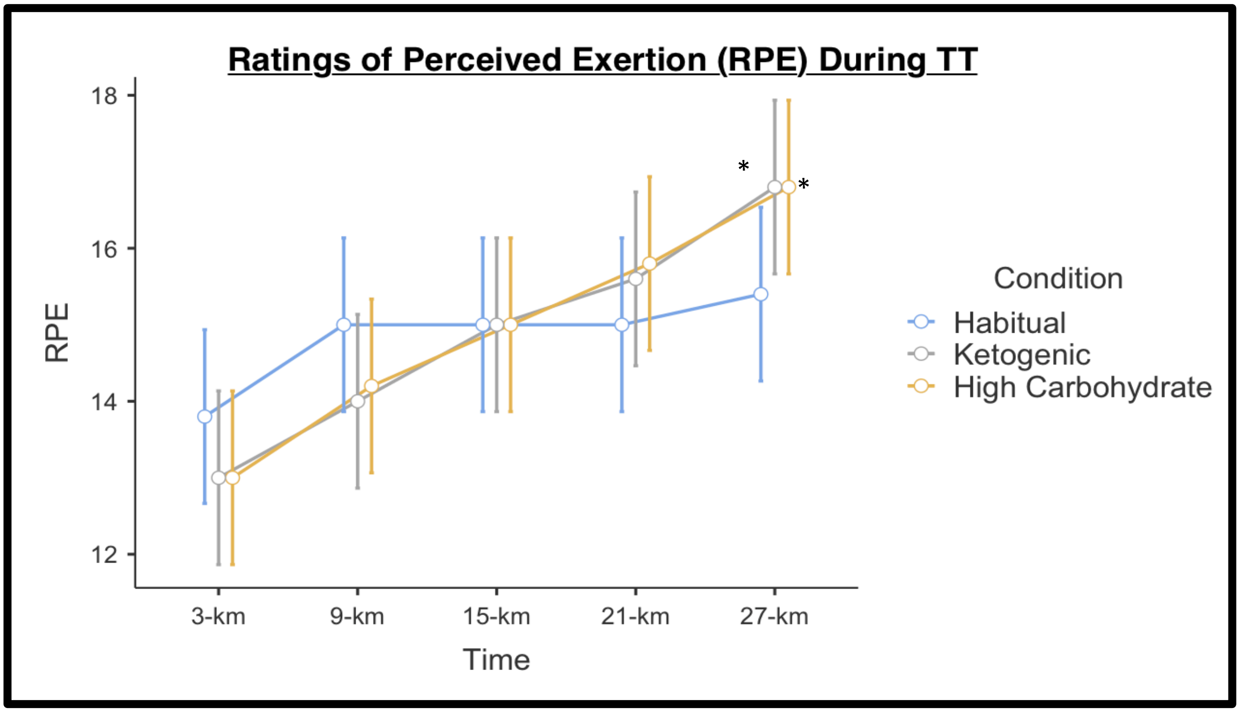


Time to complete the 30-km time-trial. There was no significant difference between conditions (p = 0.064).

Ratings on Perceived Exertion (RPE)

The effect of diet conditions on RPE throughout the 30-km time-trial is shown in **Figure 4**. Across the 30-km time-trial, there was a significant [$F(8,32) = 4.3669$, $p = 0.001$, $n^2p = 0.522$] time vs. condition interactions for RPE. In the habitual trial there was no significant difference in RPE when comparing 3-km with 27-km ($p = 0.255$). However, in the ketogenic diet, RPE was significantly greater ($p < 0.001$) at 27-km (Mean=16.8; 95%CI= 15.7-17.9) compared with 3-km (Mean=13.0; 95%CI= 11.9-14.1). Similarly, in the high-carbohydrate diet, RPE was significantly greater ($p < 0.001$) at 27-km (Mean=16.8; 95%CI= 15.7-17.9) compared with 3-km (Mean= 13.0; 95%CI= 11.9-14.1).

Figure 4.

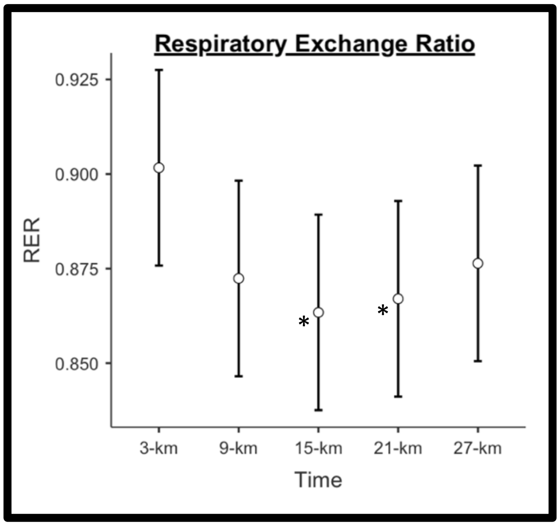


*Significantly different from 3-km in same condition

Respiratory Exchange Ratio (RER)

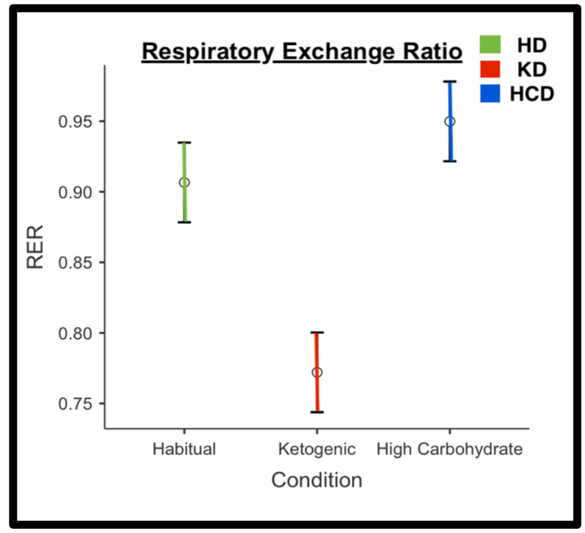
RER during the 30-km time-trial is shown in **Figure 5.** There were significant differences in RER observed across the 30-km time-points [F(4, 16) = 3.16, p = 0.021, n^2p = 0.494]. Specific significant differences include 3-km vs. 15-km (p = 0.027), and 3-km vs. 21-km (p = 0.049). Additionally, effect of diet condition on RER throughout the 30-km time-trial is shown in **Figure 6**. Significant differences in RER were observed between all diet condition groups throughout the time-trial [F(2, 8) = 73.08, p = <.001, n^2p = 0.948]. Specific differences included HD vs. KD (p = <.001), HD vs. HCD (p = 0.022), and KD vs. HCD (p = <.001).

Figure 5.



*15-km and 21-km significantly lower from 3-km

Figure 6.



All conditions were significantly different from each other.

CHAPTER 4

DISCUSSION

This study was one of the first investigate the effects of a high-carbohydrate versus ketogenic diet on exercise performance in both male and female highly trained cyclists ages 18-70. The study found no difference in the time-trial by diet condition. There was also no difference in RPE by diet condition. RER was significantly lower in the KD compared to the HCD and the HD.

Time-trial duration tended to be faster during the high-carbohydrate condition compared to the ketogenic condition. However, it did not reach statistical significance. The findings that the 30-km time-trial performance was not significantly different for participants between diet conditions is similar to those seen in past literature (17,33). Other studies (13,15,16,23), however, have showed significant improvements in time to complete a time-trial while on a high-carbohydrate diet compared to a ketogenic diet. With an increased number of participants finishing the study, it is likely we would see significance between the KD and HCD.

There was no difference in RPE by diet condition. However, RPE was higher at 27 km versus 3 km in both the HCD and KD time-trials. Burke et al. (16) reported that RPE tended to be higher in the low-carbohydrate high-fat compared to the HCD group across both pre and post trials, but the differences did not reach statistical significance. Our results were also not similar to those of Stepto et al. (20) who reported that RPE was greater during the high-fat versus high-carbohydrate diet during both the standard laboratory cycling training sessions and other training outside.

The present study found a significantly lower RER in the KD compared to the HCD and HD diets. McSwiney et al. (17) showed that RER was lower with the ketogenic diet during the time-trial. Additionally, Burke et al. (16) saw significantly lower RER values during the ketogenic dietary treatment of their study. Stepto et al. (20) showed that RER values were significantly higher on the high-carbohydrate compared to the high-fat diets during laboratory exercise sessions. Another study done by Burke et al. (33) which had participants on 6 days of high-carbohydrate compared with 5 days of low-carbohydrate consumption + 1 day carbohydrate restoration (fat-adapt) showed that RER during 120 min steady state cycling, was lower in fat-adapt compared with the high-carbohydrate diet, even with the one day of carbohydrate restoration. Our results were in accordance with all these studies.

There is an increased oxygen cost of ATP production from fat *vs*. carbohydrate oxidation which has been demonstrated for a century (34,35). Since the oxidative phosphorylation yield is higher when NADH is the electron donor compared with $FADH_2$, and carbohydrate metabolism produces a greater ratio of the reducing equivalents NADH/FADH2, than β-oxidation, carbohydrate is able to produce a greater ATP yield per unit of oxygen consumption despite the greater ATP production per unit of substrate from fat (36). In cycling, the economy and efficiency of energy transfer to speed of movement is key to performance (16). This increased ATP results in quicker energy to fuel movement which will increase speed and shorten duration to finish a time-trial. Compared to a KD, which produces greater amounts of ATP at a slower rate, this does not benefit the immediate need for fuel in performance time-trials.

In the current study it is shown that the KD down-regulates carbohydrate metabolism, shown by a decreased RER. This is due to reduced availability of carbohydrate substrate including reduced muscle glycogen stores, lower plasma glucose concentrations and the absence of exogenous intake of carbohydrate during exercise. Additionally, a reduction in glycogenolysis during exercise, and a reduction in the active form of pyruvate dehydrogenase at rest and during exercise has been shown, thus reducing the capacity for an oxidation of carbohydrate (37). Lastly, in a study that measured glucose kinetics at rest and during 2-h of cycling at a slightly higher intensity (38) it showed that endogenous glucose production at rest and during exercise in keto-adapted ultra-endurance athletes was lower compared with athletes consuming higher carbohydrate diets. These are all mechanisms in which a KD can lower RER compared to HCD and HD.

The first and main limitation of the current study is the limited sample size. We were asked to halt our study and were not able to complete an additional 5 participants because of the COVID-19 situation. Secondly, we saw a slight weight loss when participants were on the KD. This may be partly due to depleted glycogen stores on the KD resulting in loss of water weight. Body water may have an impact on ratings of perceived exertion or time-trial. However, the participants were asked to drink water ad-libitum during the trials, and this may have limited the impact of body water on the outcome variables. Percent energy from protein was higher in the KD compared to the other diets. However, past studies (39,40) have shown that cycling time-trial performance is not significantly enhanced when additional protein is consumed in one's diet. The study population was white and mostly female, and the results are not generalizable. Lastly, relative humidity was much higher during the habitual time-trial but very similar between high-carbohydrate and ketogenic diet trials. While that was the case, we did not see an order effect. Lastly dietary intervention may have had a cognitive impact which could affect RPE. This is unlikely, however, because there was no effect of order on RPE.

There were several strengths of the current study. It was a randomized cross-over design which allows inference of causation. Energy intake was the same between the three conditions and all participants showed evidence for ketosis while following the KD condition. These factors show high diet adherence. Participants did not differ in training volume or sRPE throughout the study. During experimental trial (ET) days, fluid intake was not significantly different. Additionally, study meals were equivalent in total energy content, volume of liquid, and time of consumption on each trial day. Prior research utilizing time-trial as a measure of performance (15) has justified our decision for administering a 30-km time-trial as a sufficient length to induce detectable performance effects. Time frame of exposure to each diet condition in the current study is justified by past research as enough time to adapt to each diet (23).

Future studies should consider fully controlling all intake throughout the study period by feeding participants as this would be ideal. A diverse group of cyclists need to be recruited in order to make the findings more generalizable. Future studies should also look at the effects of external factors on cyclists in these conditions in order to make results more applicable to real-world race situations. Additionally, it is important to evaluate the cognitive impact of dietary intervention on ratings of perceived exertion.

In conclusion, time required to complete a 30-km time-trial and RPE were not significantly different for participants between diet conditions. RER was significantly lower in the KD compared to HCD and HD conditions.

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APPENDIX A

MEAL PLAN

KETOGENIC: 2,500 KCAL

	Breakfast	Lunch	Dinner	Snacks
Sun	-2 scrambled eggs (cooked with 2 tbsp butter) -4 slices bacon -1 Keto Zone perfect shake (See suggestions)	-1.5 Servings White Shredded Chicken Chili (See recipe book) -1.5 C Spinach + 2 Tbsp olive oil dressing	-4 oz. Pan fried salmon -1 C Sautéed Broccoli (in olive oil, topped with 1 tbsp parmesan cheese)	-1 serving Whisps-CheeseCrisps -1 Keto Bar + 1 C coffee + 2 Tbsp Heavy cream -2 Keto Brownie Fat Bombs
Mon	-Keto Chocolate Chia seed pudding (1 Serving) (See recipe book) -1 scrambled egg -1 C coffee w/ 2 tbsp heavy cream	-6 Ham and Cheese Roll ups (See Recipe Book)	-Cheesy Bacon Ranch Chicken -1 C Roasted Veggie + 1 Tbsp olive oil	- 1/2 C whole fat yogurt, 1/4 C Keto granola, 1 Tbsp coconut flakes -2 Tbsp Ranch and 1/2 C raw veggies -1 Keto Brownie fat bomb (See recipe book)
Tue	-Sausage patty breakfast sandwich (See recipe book) -1 C coffee + 2 Tbsp heavy cream	-2 hard boiled eggs -1/4 C almonds -Keto ZonePerfect Shake	-3 Slices Cauliflower Pizza (See recipe book) -4 slices bacon to top	-2 Almond Butter Balls (See recipe book) -1/4 C cubed cheese + 4 slices of turkey -1 Serving Zucchini Crisps (See recipe book) + 2 Tbsp ranch
Wed	-1/4 C Keto Granola (See recipe book) -2 TBSP Almond Butter -1 C Coconut milk	-1 Serving Chicken Lettuce Wraps (See recipe book)	-1 Serving-Bacon Cheeseburger Casserole (See recipe book)	-1 Almond Butter Ball -1 Turkey sticks and 1/4 C cubed cheese -1 Keto Zoneperfect Shake (See options)
Thu	-Keto Breakfast Smoothie (See recipe book) -2 sausage patties	-2 Servings Chicken Cucumber Avocado Salad (See recipe book)	-1 serving Keto Chili (See recipe book)	-Cucumber and feta cheese salad (See recipe book) -Zoneperfect Keto shake -Bell Pepper keto nachos (See recipe book)
Fri	-3 egg omelette bell peppers/veggies -2Tbsp Cheese (See recipe book) -1 C coffee w/ 2 Tbsp heavy cream	-1 Serving Turkey Bacon Avocado Roll-Ups (See recipe book)-Makes 4 Turkey roll-ups	-2 servings Chicken Fried Cauliflower rice (See recipe book)	-1/4 avocado pureed with 1 Tbsp ranch & 1 serving raw veggies -Zoneperfect Shake + 1 serving Cheese whisps - 3 Cookie Dough fat bomb (See recipe book)
Sat	-1 serving-Keto Pancakes (See recipe book) -2 Tbsp SF Syrup	-2 Servings Deli Snack Box (Turkey, cheese cubes, almonds, tomatoes) (See recipe book)	- 1 Serving-Beef and Broccoli Stir fry (See recipe book)	-Keto Tuna Salad Cups (See recipe book) -2 Servings Cheesy Cauliflower Breadsticks (See recipe book) -1/4 C Low Carb Party Mix (See recipe book)

Recipes: KETO

BREAKFAST

Keto Breakfast Sandwich
Ingredients
2 sausage patties
1 egg
1 tbsp cream cheese
2 tbsp sharp cheddar
1/4 medium avocado, sliced
1/4–1/2 tsp sriracha (to taste)
Salt, pepper to taste
Instructions

1. In skillet over medium heat, cook sausages per package instructions and set aside
2. In small bowl place cream cheese and sharp cheddar. Microwave for 20-30 seconds until melted
3. Mix cheese with sriracha, set aside
4. Mix egg with seasoning and make small omelet
5. Fill omelet with cheese sriracha mixture and assemble sandwich
6. nutrition

Calories: 603
Fat: 54g
Carbohydrates: 7g Total, 4g Net
Fiber: 3g
Protein: 22g

Keto Chocolate Chia Pudding: (3 servings)
Ingredients
1 cup unsweetened almond milk
1/2 cup half and half cream
1/3 cup cocoa powder
1 tsp vanilla
1/2 tsp stevia extract
1/2 cup chia seeds
Instructions

1. Whisk together all ingredients except chia seeds until well combined.
2. Stir in chia seeds and mix well. Cover and place in refrigerator overnight or at least three hours. It might help to mix again after about 30 minutes of chilling to avoid clumps.
3. Remove from fridge, place in individual containers and place back in fridge until ready to eat. Top as desired.

Nutrition
Calories: 181kcal | Carbohydrates: 18g | Protein: 7g | Fat: 12g | Saturated Fat: 2g | Sodium: 169mg | Potassium: 261mg | Fiber: 13g | Sugar: 1g | Vitamin C: 0.4mg | Calcium: 341mg | Iron: 3.5mg

Keto Granola ¼ cup per serving

Ingredients

1 cup Almonds
1 cup Hazelnuts
1 cup Pecans
1/3 cup Pumpkin seeds
1/3 cup Sunflower seeds
6 tbsp Erythritol/xylitol(Can use stevia or monk fruit as well) sweetener
1/2 cup Golden flax seed meal
1 large Egg white
1/4 cup Butter (measured solid, then melted; can use coconut oil or ghee for dairy-free)
1 tsp Vanilla extract

Instructions

1. Preheat the oven to 325 degrees F (163 degrees C). Line a large baking sheet, or two small ones, with parchment paper. (I used two 13x9 in (33x23 cm) cookie sheets.)
2. Pulse almonds and hazelnuts in a food processor intermittently, until most of the nuts are in chopped into large pieces (about 1/4 to 1/2 of the full size of the nuts).
3. Add the pecans. Pulse again, stopping when the pecans are in large pieces. (Pecans are added later since they are softer.)
4. Add the pumpkin seeds, sunflower seeds, erythritol, and golden flaxseed meal. Pulse just until everything is mixed well. Don't over-process! You want to have plenty of nut pieces remaining, and most of the seeds should be intact.
5. Add the egg white to the food processor. Whisk together the melted butter and vanilla extract in a small bowl, and evenly pour that in, too.
6. Pulse a couple times, mix a little from the bottom toward the top with a spatula, then pulse a couple times again. Repeat as needed until everything is coated evenly. Again, avoid over-processing. At the end of this step, you'll have a combination of coarse meal and nut pieces, and everything should be a little damp from the egg white and butter.
7. Transfer the nut mixture to the prepared baking sheet in a uniform layer, pressing together into a thin rectangle (about 1/4 to 1/3 in (.6-.8 cm) thick). Bake for 15-18 minutes, until lightly browned, especially at the edges.
8. Cool completely before breaking apart into pieces. (The granola will be soft when you remove it from the oven but will crisp up as it cools.)

Nutrition Facts

Amount per serving. Serving size in recipe notes above.

Calories	278
Fat	26g
Protein	7g
Total Carbs	7g
Net Carbs	2g
Fiber	5g
Sugar	1g

3 egg omelet:

Ingredients

3 large eggs + 2 Tbsp heavy cream
2 tbsp olive oil
2 tbsp cheese
Bell peppers, mushrooms, any additional veggie desired

Instructions

1. Whisk up 3 eggs in a bowl with 2 tbsp heavy cream
2. Use 2 Tbsp butter in skillet
3. Add eggs to skillet
4. While cooking, add already cooked ham (meat of choice), cheese, and veggies
5. Fold over once edges are cooked
6. Flip to other side and cook until all egg is cooked through

Chocolate Coconut Keto Breakfast Smoothie

Ingredients

1/2 large avocado (100 g/ 3.5 oz)
1 1/4 cup almond milk (300 ml/ 10 fl oz)
1/4 cup coconut cream or heavy whipping cream (60 ml/ 2 fl oz)
1 tbsp flax meal or chia seeds (7 g/ 0.3 oz)
1 1/2 tbsp cacao powder (8 g/ 0.3 oz)
1 tsp virgin coconut oil or MCT oil
1 heaped tbsp almond butter, or other nut or seed butter) (32 g/ 1.1 oz)

Instructions:

1. Blend all ingredients together in a blender.
2. Top with optional cacao nibs or dark chocolate and whipped cream

Fluffy Almond Flour Keto Pancakes

Ingredients

2 cups fine almond flour
8 tablespoons butter, gently melted
1 tablespoon avocado oil or melted coconut oil
1/4 cup water
4 eggs
Pinch of salt
1/2 teaspoon maple extract (optional but highly recommended)
1 teaspoon vanilla extract
1 teaspoon baking powder
2 tablespoons xylitol/erythritol (Can use stevia or monk fruit as well) sweetener
Coconut oil for greasing

Instructions

1. In a blender, combine all ingredients and blend until fully combined. Your batter will be pretty thick -- that’s a good thing!

2. Heat a large nonstick skillet on medium low heat. Allow your batter to rest in the blender container for 5 minutes while your pan heats up.
3. Add enough coconut oil to coat the pan.
4. When oil has melted, add three silver-dollar sized dollops of batter to your pan. Cook until the edges look more matte and firmed up (about 3 minutes). You won’t see bubbles like you would on a non-keto pancake, so watch closely.
5. Gently check the undersides of your pancakes. When they look golden on the bottom, flip and cook for an additional minute, or until golden.
6. Repeat steps 3-5 until you run out of batter.
7. Serve almond flour pancakes warm, or cool completely and store covered in your fridge or freezer with parchment in between each layer.
8. **Can top with nut butter, sugar-free syrup

Makes: 5 Servings
Approximate nutrition facts per serving (3 silver dollar pancake):
Calories: 513
fat (grams): 49.8
sat. fat (grams): 16
carbs (grams): 13.5
net carbs: 3.9
protein (grams):15
sugar (grams):1.8
Sugar Alcohols (in grams):4.8
Fiber:4.8

LUNCH

Keto crockpot white shredded chicken chili-easy low carb slow cooking dinner

Ingredients:

2–3 lbs. Boneless, Skinless Chicken Breasts
1 Cup Chicken Stock
1 1/2 Cup Heavy Cream
8 Ounces Cream Cheese
1 & 1/2 cup diced onion
1 Cup Green Chiles
3 Teaspoons Minced Garlic
1 Teaspoon Chili Powder
1 Teaspoon Cumin
1/2 Teaspoon Cayenne Pepper (Optional)
2 Teaspoons Fresh Lime Juice
1 Tablespoon Olive Oil

nutrition facts

Serves 10
Calories Per Serving: **266**

	% DAILY VALUE		
Total Fat *16.4g*	25%	**Cholesterol** *103.4mg*	34%
Sodium *214.2mg*	9%	**Total Carbohydrate** *6.1g*	2%
Dietary Fiber *0.8g*	3%	**Sugars** *2.7g*	
Protein *23.3g*	47%	**Vitamin A** *134.6µg*	9%
Vitamin C *7.9mg*	13%		

The information shown is an estimate provided by an online nutrition calculator. It should not be considered a substitute for a professional nutritionist's advice.

Instructions:

1. Heat olive oil, lime, and garlic on medium heat in a non-stick skillet and sauté onions for 2-3 minutes until clear.
2. Set Aside.
3. Add chicken, broth, green chilis & all dry seasonings to your crockpot.
4. Add in onions & garlic.
5. Set the crockpot for 6 hours on low. Or 4 on high.
6. Walk away & move on with your life for the next few hours.
7. After 4-6 hours it's time to return to the kitchen to shred the chicken. All you have to do is stir it with a fork inside the crockpot. No need for any extra dishes or work! That's it. Chicken shredded.
8. Last Step-You're almost done! Add cream cheese followed by heavy cream & cook for another 45 minutes-1 hour.
9. Top with ¼ sliced avocado and 2 Tbsp shredded cheese

Ham and Cheese Roll-Ups

Ingredients:

3 string cheese sticks
3 pieces of ham
3Tbsp Cream Cheese

Instructions:

1. Spread 1 Tbsp cream cheese on each piece of ham
2. Take string cheese and roll up in pieces of ham

Chicken Lettuce Wraps (Serves 2-3)

Ingredients

2 chicken breasts or thighs
1/2 beefsteak tomato, diced
1/2 avocado, diced
1/2 lb. bacon

Ranch dressing
Boston Bibb, romaine, or iceberg lettuce
1/4 cup chopped cilantro
1/2 lime
Salt and pepper for seasoning (or chili lime seasoning if you have it)

Instructions

3. Start by seasoning the chicken with salt and pepper, then grill them (you could do stovetop as well).
4. Meanwhile, bake your bacon on a foil lined cookie sheet at 420°. Start checking for doneness at 15 minutes but it will likely take closer to 20.
5. I had used ends and pieces, so they came already chopped, but if you use regular slab bacon crumble it up after it's cooked.
6. When the chicken is done, cut it up into bite sized pieces and mix the cilantro in.
7. Wash the lettuce, and carefully remove each leaf so that it creates a boat, or cup to put the yumminess in.
8. Now set all your ingredients out so people can build their own lettuce wrap. Squeeze the half a lime over the avocado, tomato, and chicken.
9. Take the lettuce leaf, fill it with the bacon, avocado, tomato, and chicken. Then drizzle with ranch.
10. Eat it like a taco and enjoy!

Turkey Bacon Avocado Roll-Ups

Ingredients

6 Slices Turkey
3-6 Butter Lettuce Leaves
2 Ounces Mashed Avocado
1/2 Small Tomato, Sliced
3 Slices Cooked Bacon
Salt and Pepper to taste

Instructions

1. Stack two slices of Turkey on a work surface.
2. Lay one to two butter lettuce leaves on top.
3. Smear a spoonful of avocado on top of the lettuce, followed by a tomato slice and a piece of bacon.
4. Season with salt and pepper
5. Roll from one end to the other to create a turkey roll up.
6. Repeat the process 2 more times to make 3 turkey roll ups.
7. Notes
8. You can use any lunchmeat variety that you like. The thin quality of the lunchmeat is what helps these not unroll.
9. I used already prepared mashed avocado that was seasoned with vinegar, jalapeno, onion, and garlic.
10. I used my method for oven cooked bacon to get my bacon nice and crispy.

Nutrition
Calories: 448kcal

Chicken Cucumber Avocado Salad
Servings: 6 people
Ingredients
1 Rotisserie chicken deboned and shredded (skin on or off)
1 large English (or continental) cucumber, halved lengthways and sliced into 1/4-inch thick slices
4-5 large Roma tomatoes sliced or chopped
1/4 red onion thinly sliced
2 avocados peeled, pitted and diced
1/2 cup flat leaf parsley chopped*
3 tablespoons olive oil
2-3 tablespoons lemon juice (or the juice of 2 limes)
Salt and pepper to taste
Instructions

1. Mix together shredded chicken, cucumbers, tomatoes, onion, avocados, and chopped parsley in a large salad bowl.
2. Drizzle with the olive oil and lemon juice (or lime juice), and season with salt and pepper. Toss gently to mix all of the flavors through.
3. Notes

*Substitute parsley with fresh basil or cilantro
Nutrition
Calories: 545kcal | Carbohydrates: 10g | Protein: 40g | Fat: 38g | Saturated Fat: 8g | Cholesterol: 121mg | Sodium: 127mg | Potassium: 868mg | Fiber: 5g | Sugar: 2g | Vitamin A: 1050IU | Vitamin C: 22.7mg | Calcium: 46mg | Iron: 3mg

Deli Snack Box
Ingredients
2 ounces thinly sliced turkey breast
1 large egg, hard boiled
1/4 cup cherry tomatoes
1-ounce sharp cheddar cheese, cubed
2 tablespoons raw almonds
Instructions
Place turkey, egg, tomatoes, cheese, and almonds into meal prep containers.

DINNER

Cheesy Bacon Ranch Chicken

Ingredients

4 slices thick-cut bacon
4 boneless skinless chicken breasts (about 1 3/4 lbs.)
Kosher salt
Freshly ground black pepper
2 tsp. ranch seasoning
1 1/2 c. shredded mozzarella
Chopped chives, for garnish

Instructions

1. In a large skillet over medium heat, cook bacon, flipping once, until crispy, about 8 minutes. Transfer to a paper towel–lined plate. Drain all but 2 tablespoons of bacon fat from the skillet.
2. Season chicken with salt and pepper. Return skillet to medium-high heat, add chicken and cook until golden and just cooked through, about 6 minutes per side.
3. Reduce heat to medium and sprinkle chicken with ranch seasoning and top with mozzarella. Cover the skillet and cook, until cheese is melted and bubbly, about 5 minutes.
4. Crumble and sprinkle bacon and chives on top before serving.

Low Carb Pizza Margherita With Cauliflower Crust

Servings 6 slices
Calories 130 kcal

Ingredients

12 ounces cauliflower florets
2 ounces shredded cheddar cheese
1 ounce (1/4 cup) finely grated parmesan cheese
2 large eggs
2 teaspoons dried oregano
1/2 teaspoon salt
Margherita Toppings:
1/4 cup tomato sauce
1 ounce thinly sliced fresh mozzarella cheese
1/2 tablespoon olive oil
5 basil leaves cut into strips
coarsely ground black pepper

Instructions

1. Position an oven rack in the center of the oven. Preheat to 425 F. Prepare a large baking sheet lined with parchment paper or a baking mat.
2. Using a food processor or box grater, grate the cauliflower florets. In a bowl, stir with salt until well-mixed.
3. Using a nut milk bag or cheese cloth, squeeze moisture from the grated cauliflower, discarding about 1/2 cup of liquid.

4. In a large mixing bowl, combine grated cauliflower, cheddar cheese, parmesan cheese, eggs, and oregano. Stir until well-mixed.
5. Transfer the mixture onto the lined baking sheet. Cover with overlapping sheets of plastic cling wrap. Spread and flatten into a 9-10-inch diameter circle. Discard the plastic wrap.
6. Bake at 425 F until the top is golden, about 20 minutes. After baking, remove the pizza from the oven and add desired toppings.
7. For margherita style toppings, use a spoon to spread the tomato sauce evenly across the surface. Distribute mozzarella cheese on top of the sauce. Drizzle with olive oil and season with black pepper.
8. Return to the oven and bake for another 5 minutes or until the crust looks crispy and the toppings are heated through. Top with basil. Cut into slices and serve.

Nutrition Info
This recipe yields 2 g net carbs per serving (1 slice or 1/6 of the recipe).

Nutrition Facts Per Serving	
Calories 130	
Total Fat 9g	14%
Saturated Fat 4g	21%
Trans Fat 0g	
Cholesterol 82mg	27%
Sodium 400mg	17%
Potassium 10mg	0%
Total Carb 3.5g	1%
Dietary Fiber 1.5g	7%
Sugars 2g	
Protein 9g	

Vitamin A 6% · Vitamin C 41% · Calcium 19% · Iron 4%

HFLC Bacon Cheeseburger Casserole
Servings: 6
Total Carbs: 3g
Ingredients
Beef Layer
1 onion quartered and sliced
1 clove garlic crushed
750 g ground/mince beef
60 g cream cheese full fat
3 slices bacon diced
salt/pepper to taste
Cheats Cheese Sauce
3 eggs - medium
125 ml heavy cream
100 g shredded/grated cheese

2 tbsp mustard
2 gherkins/pickles sliced
salt/pepper to taste
50 g shredded/grated cheese to sprinkle over

Instructions

Beef Layer

Fry the bacon pieces until cooked then remove and set aside.

Fry the onion, garlic and beef until thoroughly cooked. Add salt and pepper to taste, stir through the cream cheese.

Pour the beef layer into the baking dish. Sprinkle the bacon pieces over.

Cheats Cheese Sauce

Mix the eggs, cream, shredded/grated cheese, mustard, salt and pepper together. Pour the cheese sauce over the beef and bacon.

Place slices of gherkins/pickles all over the top then cover with the remaining shredded/grated cheese.

Bake at 180C/350F for 15 minutes until the cheese is golden and crispy.

Calories: 613kcal | Carbohydrates: 3g | Protein: 33g | Fat: 51g | Sugar: 1g

<u>Keto Chicken Fried Cauliflower Rice (4 Servings)</u>

Ingredients

1 small head of cauliflower, riced
1 tablespoon coconut oil
1/4 cup onion, chopped
1-pound uncooked chicken breast, cubed
1/2 teaspoon garlic powder
Salt and pepper, to taste
1 tablespoon sriracha
2 tablespoons soy sauce or liquid aminos, divided
2 cups broccoli, cut into small florets
2 tablespoons water
1 egg
1 stalk green onion, sliced
1 teaspoon sesame seeds

Instructions

1. Remove core and leaves from cauliflower. Cut into florets and place into food processor. Pulse until rice-like texture, set aside in large bowl. Use steamer bag of pre-riced cauliflower, if preferred. ~4 cups.
2. In skillet over medium heat, place coconut oil. When melted, add onion to pan and sauté until fragrant.
3. Add chicken to skillet and sprinkle with garlic powder, salt and pepper. Sauté chicken until cooked through and golden.
4. Pour sriracha and half of soy sauce into pan to coat chicken.
5. Add broccoli and water to pan and cover. Allow to steam for about 5-7 minutes, until it begins to soften.
6. Place cauliflower rice in pan, sprinkle with a little salt and add remaining soy sauce.

7. Gently stir so cauliflower rice is coated. Continue cooking for about 15-20 minutes until broccoli is fork tender and cauliflower rice is soft.
8. Push the cauliflower rice and veggies to the edges of the pan leaving a hole in the center. Crack the egg open in the center of the pan. Let it fry, breaking the yolk apart with a fork.
9. Once the egg is completely cooked, gently mix it in with the cauliflower rice. Garnish with sliced green onions and sesame seeds, if desired.

Nutrition Information:
YIELD:
4 Servings
SERVING SIZE:
1/4 of Recipe
Amount Per Serving: CALORIES: 289 TOTAL FAT: 9.2g CARBOHYDRATES: 10.74 Total, 7.65 Netg FIBER: 3.09g PROTEIN: 39.6g

Keto Chili Recipe

Ingredients

2 pounds lean ground beef (cooked and drained)
1 small onion, chopped
3 bell peppers, seeded and diced
5 cloves garlic, minced
2 (15oz) cans diced tomatoes
1 1/2 cups beef stock
2 Tablespoons chili powder
1/4 teaspoon cayenne pepper (or more to taste)
1/4 teaspoon Italian seasoning
6-8 turns freshly ground black pepper
1/2 teaspoon sea salt

Instructions

1. Add everything to the slow cooker and stir together.
2. Cook on Low for 6-7 hours or High 3-4 hours.

Paleo Keto Beef and Broccoli Stir Fry (4 servings)

Ingredients

1 1/2 lbs. thinly sliced beef strips
1 lb. broccoli, break into florets
6 oz thinly sliced mushrooms
1 tsp grated ginger
4 cloves garlic minced
1 tbsp sesame oil
1/4 cup + 1 tbsp oyster sauce
1/4 tsp red pepper flakes, crushed
3 tbsp olive oil
1/4 cup beef broth

Instructions

1. Mix Beef broth, sesame oil, ginger , oyster sauce , fish sauce , red pepper flakes and garlic in a Bowl .

2. Combine Thin beef strips into the mixture and marinate over an hour.
3. Heat a wok on a high heat, add olive oil, once hot add broccoli and stir fry for 2 mins.
4. Add the marinated beef strips and cook for 2 mins then add left over sauce and mushrooms and cook until beef is done.

Nutrition Information:
YIELD:
4
SERVING SIZE:
4 people
Amount Per Serving: CALORIES: 681 TOTAL
FAT: 48g CARBOHYDRATES: 8g PROTEIN: 50g

SNACKS

Cucumber Tomato Feta Salad
Servings 4
Calories 149 kcal

Ingredients

2 1/2 cups English cucumber, diced
1 cup Feta cheese, coarsely chopped
.5 cup grape or plum tomato, chopped
2 tablespoons red onion, fine diced
1/2 tsp fresh thyme leaves, preferably lemon thyme
1 tbsp olive oil
2 tsp fresh lemon juice
fresh ground pepper and sea salt to taste

Instructions

1. Simply combine cucumbers tomatoes and onion in a large bowl. Mix in the thyme oil and lemon juice then fold in the feta and gently toss to coat.
2. Season to taste with salt and pepper.
3. Serve small bowl as appetizer or side dish.

Nutrition Facts
Cucumber Tomato Feta Salad

Amount Per Serving	
Calories 149	Calories from Fat 108
	% Daily Value*
Fat 12g	**18%**
Saturated Fat 6g	**38%**
Cholesterol 33mg	**11%**
Sodium 422mg	**18%**
Potassium 207mg	**6%**
Carbohydrates 6g	**2%**
Fiber 1g	**4%**
Sugar 4g	**4%**
Protein 6g	**12%**
Vitamin A 535IU	**11%**
Vitamin C 8.3mg	**10%**
Calcium 199mg	**20%**
Iron 0.5mg	**3%**

* Percent Daily Values are based on a 2000 calorie diet.

Keto No-Bake Brownie Bites (18 servings)

Ingredients

1 Cup Whole Walnuts
1/8 tsp. Sea Salt
1/4 Cup Cocoa Powder
1/2 Cup Almond or Peanut Butter
1/4 C Erythritol or Swerve or granulated sweetener of choice
2 Tbsp. Coconut Flour or as needed
1/4 Cup Enjoy Life Dark Chocolate Chips or chocolate chips of choice
1/2 tsp. Pure Vanilla

Instructions

1. In the bowl of a food processor add the walnuts and sea salt. Process until walnuts are finely ground.
2. Add the cocoa powder, nut butter, vanilla, and Swerve (or sweetener of choice) and process until well combined and batter starts coming together.
3. Depending on the thickness of your nut butter you may need to add coconut flour to help bind everything together. If so, add the coconut flour 1 Tbsp. at a time, and process until well combined, until you achieve the right consistency. (if you add too much flour, just add in a splash of non-dairy milk)
4. Pulse in the chocolate chips.
5. Line a baking sheet with parchment paper.
6. Roll the dough between the palms of your hand to form small balls and place on the parchment paper.
7. Place the baking sheet in the freezer for 10-20 minutes or until firm.
8. Store in a sealed baggie or container in the refrigerator.

Notes
A reader commented that to make these lower carb you can sub the walnuts or pecans and the nutritional info will be as follows:
kcal: 98.3net carbs: 1.68 (7.65g carbs – 2.29g fiber – 3.68 sugar alcohols = 1.68 net carbs each),fats: 9.14g.
Calories: 110kcal | Carbohydrates: 5g | Protein: 3g | Fat: 9g | Saturated Fat: 1g | Sodium: 17mg | Potassium: 98mg | Fiber: 2g | Vitamin C: 0.1mg | Calcium: 32mg | Iron: 1.2mg

Almond Butter Balls

Ingredients

4 oz Coconut Oil
2 oz Butter
6 oz Almond Butter
1 tbs Cocoa Powder
4 tbs Coconut Flour
1/2 tsp Pink Salt
20 drops Liquid Stevia

Instructions

1. In a microwave safe bowl or a saucepan melt the coconut oil, butter, and almond butter.
2. Add in the rest of the ingredients and mix well.
3. Once combined pour into molds or a bowl and place in the freezer for about an hour in a mold or 30 mins in the bowl.
4. If using a bowl take a cookie scoop and form into balls.
5. Place on a cookie sheet and place back in the freezer for another 30 minutes.
6. Store in the fridge and enjoy!

Nutrition Information:
YIELD: 12 SERVING SIZE: 1 fat bomb
Amount Per Serving: CALORIES: 150 TOTAL FAT: 15g SATURATED FAT: 13.1g CHOLESTEROL: 15mg SODIUM: 50mg CARBOHYDRATES: 3g FIBER: 2g SUGAR: .5g PROTEIN: .5g

Cookie Dough Fat Bombs

Ingredients

2 tbsp (16g) finely ground almond flour
1 tbsp (8g) finely ground coconut flour
1 ½ tbsp (20g) granulated erythritol
2 tbsp (30g) softened butter
1 ½ tbsp (20g) sugar-free chocolate chips
½ tsp sugar-free vanilla extract

Instructions

1. Mix all of the ingredients in a middle-sized bowl until you get a smooth and chunk-free mass. You shouldn't have any large chunks of flour or butter left and the chocolate chips should be distributed evenly throughout the mass.
2. Optional: Place in freezer for approx. 10-15 minutes for easier rolling of the balls. Separate the mass into 4-5 equal parts and roll them in between your hands until you get small round balls.
3. Eat right away like true cookie dough or store in your fridge covered with plastic wrap for approx. 3-4 days.

Nutrition Facts

Serving Size 1 fat bomb (approx. 0.6 oz/ 17g)
Servings 5

Amount Per Serving	
Calories 90	
	% Daily Value *
Total Fat 8g	13%
Total Carbohydrate 2.3g	1%
Dietary Fiber 1.3g	6%
Protein 2.4g	5%

* Percent Daily Values are based on a 2,000 calorie diet. Your daily value may be higher or lower depending on your calorie needs.

Mexican Mini Bell Pepper Nachos

Servings 6 People
Calories 190 kcal

Ingredients

1/2 lb. Lean ground beef (I used 93%)
26 Mini peppers
6 Tbsp Salsa
1 cup Grated Mexican cheese blend, packed (4 oz)
1/2 cup Tomato diced
1 Large avocado, diced
1/4 cup Green onion diced
Chopped cilantro, for garnish
Optional dips: salsa, guacamole, sour cream etc.

Instructions

1. Heat a medium pan on medium high heat and cook the ground beef, breaking it up as it cooks, until no longer pink inside. Also, preheat your oven to 400 degrees.
2. Cut the stem off each pepper and cut in half, removing the seeds and white flesh. Spray a baking sheet with cooking spray and arrange the peppers so that the cut sides are facing up.
3. Stir the salsa into the cooked beef and fill the peppers with the beef. Sprinkle with the cheese.
4. Bake until the cheese is melted, about 5-7 minutes.
5. Sprinkle on the tomato, green onion, avocado and cilantro.
6. DEVOUR immediately, with optional dips!

Keto Tuna Salad Cups

Yield: 8 servings

Ingredients

4 large eggs
4 strips bacon
1/3 cup olive or avocado oil mayonnaise

2 tablespoons sour cream
1/4 teaspoon lemon zest plus 1 tablespoon lemon juice
1 stalk celery, thinly sliced
Two 5-ounce cans tuna packed in olive oil, 2 tablespoons of the oil reserved and the rest drained
2 scallions, sliced
Kosher salt and freshly ground black pepper
1 medium tomato, halved and cut into 8 slices
16 leaves Bibb lettuce

Instructions

1. Cover the eggs with about an inch of water in a medium pot. Bring to a boil, remove from the heat, cover and let stand for 8 minutes. Drain and submerge in ice water. When cool enough to handle, peel the eggs and chop.
2. Meanwhile, cook the bacon in a large nonstick skillet over medium heat until golden and crisp, about 4 minutes per side. Remove to a paper towel-lined plate. Crumble into bite-size pieces.
3. Whisk together the mayonnaise, sour cream, lemon zest and juice, celery, reserved tuna oil, three-quarters of the scallions, 1/4 teaspoon salt and several grinds of pepper in a medium bowl. Add the tuna and three-quarters of the bacon and egg and gently fold together (do not overmix). Season with additional salt and pepper if needed.
4. Sprinkle the tomato slices with salt and pepper.
5. Double-up the lettuce leaves and fill each with some tuna salad. Tuck in a tomato slice. Sprinkle with reserved scallions, bacon and egg.

Nutritional Analysis	Per Serving
Calories	250
Total Fat	20 grams
Saturated Fat	5 grams
Cholesterol	125 milligrams
Sodium	380 milligrams
Carbohydrates	4 grams
Dietary Fiber	1 grams
Protein	14 grams
Sugar	2 grams

Cheesy keto cauliflower bread sticks

Servings: 8 people
Calories: 102kcal

Ingredients

1 1/2 cups cauliflower riced (about 3.75 ounces)
1 1/2 cups Monterey jack cheese freshly grated (about 6 ounces)
2 large eggs beaten
1/2 teaspoon ground sage
1/2 teaspoon ground oregano
1/2 teaspoon dried thyme
1/4 teaspoon ground mustard
ground black pepper to taste
fresh parsley minced (for garnishing)

Instructions

1. Remove the base or leaves and cut cauliflower into florets. rice cauliflower by using a food processor. cook for about 8 to 10 minutes, you can use a microwave or a toaster oven. allow to cool.
2. Pre-heat oven at 450f.

3. Once riced cauliflower has cooled, place in a kitchen towel and strain the liquid. transfer to a mixing bowl.
4. Season cauliflower with sage, oregano, thyme and mustard seed. mix well.
5. Season egg with ground black pepper. pour beaten egg, 3 tablespoon cheese and combine with seasoned cauliflower. allow for eggs to set at the bottom of the bowl and spoon the excess eggs out.
6. In a greased baking sheet, spread cauliflower until about 1/4-inch-thick, rectangular shape.
7. For the heart-shaped cauliflower “bread” sticks, use a heart-shaped cookie cutter. 1/2 cup of cauliflower mixture makes about 9 heart-shaped in different sizes. bake for about 8 to 10 minutes. top with 1/2 cup cheese and bake in the oven for 5 more minutes or until cheese is melted and golden.
8. For the remaining 1 cup of cauliflower mixture formed into a rectangular shape, bake for about 10 to 15 minutes. top with the remaining cheese and bake for 5 to 8 minutes or until cheese is melted and golden in color.
9. Cool for about 2 to 3 minutes and slice with a pizza cutter.
10. Garnish with freshly minced parsley. Serve with marinara sauce (low carb).

Nutrition
serving: 47g | calories: 102kcal | carbohydrates: 1.1g | protein: 7.1g | fat: 7.7g | saturated fat: 4.4g | cholesterol: 65mg | sodium: 135mg | potassium: 77mg | sugar: 0.5g | vitamin a: 250iu | vitamin c: 8.3mg | calcium: 170mg | iron: 0.5mg
additional info
net carbs 1.1g
% carbs: 4.3%
% protein: 27.8%
% fat: 67.9%

Low Carb Party Mix Recipe
Low Carb Party Mix with just 4-Ingredients. Perfect combination of something sweet to snack on while hanging out with friends this week.
Yield: 2 cups
Calories: 166 kcal
Ingredients
1/2 cup walnut pieces
1/2 cup pecan halves
1/2 cup low carb chocolate chips
1/2 cup unsweetened coconut flakes
Instructions
1. Toss all ingredients together and serve.

Nutrition Facts
Low Carb Party Mix Recipe

Amount Per Serving (0.25 cup)	
Calories 166	Calories from Fat 144
	% Daily Value*
Fat 16g	**25%**
Saturated Fat 5g	**31%**
Trans Fat 0g	
Polyunsaturated Fat 5g	
Monounsaturated Fat 4g	
Cholesterol 0mg	**0%**
Sodium 1mg	**0%**
Potassium 19mg	**1%**
Carbohydrates 8g	**3%**
Fiber 5g	**21%**
Sugar 0g	**0%**
Protein 3g	**6%**

* Percent Daily Values are based on a 2000 calorie diet.

Low-Carb Zucchini Crisps

Ingredients

2 large zucchinis, thinly sliced
1 tablespoon olive oil, or to taste
sea salt to taste

Instructions

2. Preheat oven to 250 degrees F (120 degrees C).
3. Arrange sliced zucchini on a baking sheet. Drizzle lightly with olive oil and sprinkle lightly with sea salt.
4. Bake in the preheated oven until completely dried and chip-like, about 1 hour per side. Allow to cool before serving.

Nutritional Information

Low-Carb Zucchini Chips

Servings Per Recipe: 2
Amount Per Serving
Calories: 111

	% Daily Value *
Total Fat: 7.3g	11 %
Saturated Fat: 1.0g	
Cholesterol: 0mg	0 %
Sodium: 192mg	8 %
Potassium: 848mg	24 %
Total Carbohydrates: 10.8g	3 %
Dietary Fiber: 3.6g	14 %
Protein: 3.9g	8 %
Sugars: 6g	
Vitamin A: 646IU	
Vitamin C: 55mg	
Calcium: 49mg	
Iron: 3mg	
Thiamin: 0mg	
Niacin: 2mg	
Vitamin B6: 1mg	
Magnesium: 57mg	
Folate: 94mcg	

KETO BAR/SNACK SUGGESTIONS:

-Perfect Keto Bars (Flavors: Cinnamon Roll, Chocolate Chip Cookie Dough, Salted Caramel, Almond Butter Brownie, Lemon Poppyseed): 210-230 calories
-SlimFast Keto Meal Bars (Flavors: Peanut Butter Chocolate, Salted Caramel Macadamia Nut, Whipped Triple Chocolate, Nutty Caramel and Nougat, Chocolate Chip Cookie Dough): 180-190 calories
-Stoka Bars (Flavors: Cocoa Almond, Sea Salt Caramel, Peanut Chocolate Chip, Vanilla Almond, PB&J Strawberry, Lemonade, Chocolate Chip Almond, Sea Salt Caramel, Cherry Almond) : 230-250 calories
-Keto Bars (Flavors: Chocolate Peanut butter, Dark Chocolate Coconut Almond, Mint Chocolate): 220-250 calories
-Smartcakes: (Flavors: Chocolate, Cinnamon, Lemon, Raspberry): 96 calories per pack

KETO SHAKE SUGGESTIONS:

-ZonePerfect Ready to Drink

APPENDIX B

MEAL PLAN

HIGH CARB: 2,500 KCAL

	Breakfast	Lunch	Dinner	Snacks
Sun	-2 C whole grain cereal -1 C blueberries -1 tbsp honey -1 C non-fat milk 1 C Orange juice	-1 C cooked rice -1/2 C black beans -1/2 C mixed vegetables (corn, carrots, peas) -Piece of fruit	-Pesto Cavatapi w/ parmesan crusted chicken (See recipe book) -1 cup steamed vegetables	-1 granola bar (See suggestions) + 1 NAKED fruit juice smoothie -Fruit Smoothie (See recipe book) -1 banana + 1 Serving medjool dates
Mon	-1 C cooked Oatmeal -1 large apple -2 Tbsp brown sugar -1 C Orange juice	-Grilled cheese sandwich -1/2 C tomato soup -1 C Grapes	-Sweet Potato Broccoli Quinoa bowl (See recipe book)	-4 Rice cakes with 4 tbsp apple butter -1 cup vanilla greek non-fat yogurt and 1/2 berries + 1 Tbsp honey + 1 serving medjool dates -1 cup cereal, 1/2 C non-fat milk + 1 banana
Tue	-2 pieces of toast -2 tbsp jam -1 cup/piece fruit -1 cup low-fat chocolate milk	-1 C cottage cheese -1 C mandarin oranges in juice -1 serving graham crackers	-1 serving Stir Fry (See recipe book) -1 C Brown Rice	-2 servings of pretzels + 1 NAKED Fruit juice smoothie -1 granola bar (See suggestions) +1 Banana -1 C vanilla nonfat yogurt + 1/2 C berries +1 tbsp honey
Wed	-2 waffles (See suggestions) -1/4 C maple syrup -1 C berries -1 C orange juice	-1 baked potato -Top with 1/2 C bean chili (See recipe) -1 NAKED Fruit juice smoothie	-6 oz. grilled Cod fish (or other low-fat fish) -1 C Cauliflower -1 C Brown rice	-1 bagel with 2 Tbsp low-fat cream cheese + 1 tbsp honey -1 granola bar (See suggestions) -1 C cereal + 1/2 C nonfat milk
Thu	-1 cup vanilla yogurt -1/2 cup granola (See suggestions) -1/2 cup berries -Honey drizzle	-Peanut butter and jelly sandwich -1 piece of fruit -1 C non-fat milk	-1 Serving Turkey Lasagna -1 C roasted veggies -1 cup juice	-1/4 C Trail mix with dried fruit & nuts + 1 bottle gatorade -1 Granola bar (See suggestions) + 1 C juice -NAKED Fruit juice smoothie + 2 medjool date
Fri	-Fruit smoothie (See recipe book) -Granola bar (See suggestions)	-4 oz. grilled shrimp -1 C pasta -1/2 C broccoli -1 bottle Gatorade	-4 oz. Grilled Chicken -1 large sweet potato -1 cup kernel corn -1 C juice	1/2 C berries + 1 Tbsp honey + 1/4 C low fat granola -2 energy balls (See recipe book) + 1 medjool date + 1 cup skim milk -1 serving wheat thins and a piece of fruit
Sat	-1 Honey whole wheat bagel -1 tbsp PB/Nut Butter + 1 Tbsp jam -1 cup berries -1 cup orange juice	-1 Cup carrot/celery sticks -2 tbsp hummus -1 apple + 2 medjool dates -1 serving pretzels	-1 Serving Capellini with Chicken, Broccoli, and Pecorino Cheese	-Fruit smoothie (See recipe book) -1 granola bar (See suggestions) and a banana -1 cup cereal, 1/2 C milk + 1 Tbsp honey

Recipes- High Carbohydrate

BREAKFAST

Smoothies:

Classic Green:
To make it, blend together:

- 1 frozen banana
- 1 cup greens (baby spinach, destemmed kale, collards, chard, etc.)
- 1 cup unsweetened rice milk or non-fat milk
- Honey or maple syrup, to taste

Orange Creamsicle:
To make it, blend together:

- 1 frozen banana
- 1 orange, peeled or 2 clementine's, peeled
- 1/2 cup plain yogurt
- 1/2 teaspoon vanilla extract
- 1 cup unsweetened rice milk or non-fat milk
- Honey or maple syrup, to taste

Chocolate PB:

- To make it, blend together:
- 1 frozen banana
- 1 cup unsweetened rice milk or non-fat milk
- 1 tablespoon natural peanut butter
- 1–3 teaspoons unsweetened cocoa powder

- Honey or maple syrup, to taste

Creamy Peanut Butter Banana:
To make it, blend together:
- 2 frozen bananas
- 2 tablespoons natural peanut butter
- 1 cup unsweetened rice milk or non-fat milk
- 1/2 cup plain yogurt
- Honey or maple syrup, to taste

Pina Colada:
To make it, blend together:
- 2 frozen bananas
- 1 cup pineapple chunks (canned or fresh)
- 1 cup coconut milk (from the can)
- Honey or maple syrup, to taste

Strawberry Banana:
To make it, blend together:
- 1 frozen banana
- 1/2 cup frozen strawberries
- 1 cup unsweetened rice milk or non-fat milk
- 1/2 cup plain yogurt
- Honey or maple syrup, to taste

Mocha:
To make it, blend together:
- 1 frozen banana
- 1 cup strong-brewed coffee
- 1 tablespoon unsweetened cocoa powder
- 1/2 cup plain yogurt
- Honey or maple syrup, to taste

Mixed Berry:
To make it, blend together:
- 1 frozen banana
- 1 cup frozen mixed berries
- 1 cup unsweetened rice milk or non-fat milk
- 1/2 cup plain yogurt
- Honey or maple syrup, to taste

LUNCH

Vegetarian Black Bean Chili
Servings: 8
Ingredients
- 1/4 cup olive oil
- 2 cups chopped onions
- 1 2/3 cups coarsely chopped red bell peppers (about 2 medium)
- 6 garlic cloves, chopped
- 2 tablespoons chili powder
- 2 teaspoons dried oregano
- 1 1/2 teaspoons ground cumin
- 1/2 teaspoon cayenne pepper
- 3 15- to 16-ounce cans black beans, drained, 1/2 cup liquid reserved
- 1 16-ounce can tomato sauce
- Chopped fresh cilantro
- Sour cream
- Grated Monterey Jack cheese
- Chopped green onions

Instructions
1. Heat oil in heavy large pot over medium-high heat. Add onions, bell peppers, and garlic; sauté until onions soften, about 10 minutes. Mix in chili powder, oregano, cumin, and cayenne; stir 2 minutes. Mix in beans, 1/2 cup reserved bean liquid, and tomato sauce. Bring chili to boil, stirring occasionally. Reduce heat to medium-low and simmer until flavors blend and chili thickens, stirring occasionally, about 15 minutes. Season to taste with salt and pepper.
2. Ladle chili into bowls. Pass chopped cilantro, sour cream, grated cheese, and green onions separately.

NUTRITION Per Serving: Calories: 315, Fat: 8g, Carbohydrates: 47g, Protein: 17g

DINNER

Pesto Cavatappi w/ Chicken
Servings: 8
Ingredients

- 8 oz uncooked cavatappi pasta (from 16-oz box)
- 1 tablespoon olive oil
- 1 package (20 oz) boneless skinless chicken breasts, cut into 1-inch pieces
- ½ teaspoon salt
- ¼ teaspoon ground black pepper
- 2 large plum (Roma) tomatoes, seeded and chopped (about 1 cup)
- 1 cup sliced fresh mushrooms (from 8-oz package)
- 1 container (7 oz) refrigerated pesto sauce
- ¾ cup heavy whipping cream

Instructions

1. Cook and drain pasta as directed on box.
2. Meanwhile, in 12-inch nonstick skillet, heat oil over medium-high heat. Add chicken, salt and pepper; cook 5 to 7 minutes, stirring occasionally, until browned and no longer pink in center. Stir in tomatoes and mushrooms. Reduce heat to medium; cook 3 to 4 minutes, stirring occasionally, until thoroughly heated.
3. Stir in pesto sauce and whipping cream; cook 2 to 3 minutes longer or until thoroughly heated. Stir in pasta, tossing to coat.

Serving Size: **1 Serving**

Calories 440	**Calories from Fat** 240	
Total Fat	26g	40%
Saturated Fat	9g	44%
Trans Fat	0g	
Cholesterol	80mg	26%
Sodium	510mg	21%
Potassium	290mg	8%
Total Carbohydrate	27g	9%
Dietary Fiber	2g	9%
Sugars	2g	
Protein	23g	

% Daily Value*:

Vitamin A 10%	Vitamin C 2%
Calcium 10%	Iron 15%

Exchanges:
1 1/2 Starch; 0 Fruit; 0 Other Carbohydrate; 0 Skim Milk; 0 Low-Fat Milk; 0 Milk; 1/2 Vegetable; 2 1/2 Very Lean Meat; 0 Lean Meat; 0 High-Fat Meat; 5 Fat;

Sweet Potato Broccoli Quinoa Bowl
Servings: 4 servings
Calories 503 kcal

Ingredients

- 3 cups sweet potato cubes cut into ½-¾ inch cubes
- 3 Tbsp. olive oil divided
- ¾ tsp. salt divided
- ½ tsp. pepper divided
- 1 head broccoli cut into florets

Quinoa in Rice Cooker:

- ¾ cup quinoa rinsed and drained
- 1 ½ cups water or chicken broth
- ¼ tsp. Salt

Quinoa Bowls:

- 1 cup cherry tomatoes cut in half
- 4 oz. cooked chicken cut into cubes
- 4 cups kale coarsely chopped

Nutrition Facts
Sweet Potato Broccoli Quinoa Bowls

Amount Per Serving	
Calories 503	Calories from Fat 225
	% Daily Value*
Fat 25g	**38%**
Saturated Fat 4g	**25%**
Cholesterol 21mg	**7%**
Sodium 1010mg	**44%**
Potassium 1028mg	**29%**
Carbohydrates 53g	**18%**
Fiber 5g	**21%**
Sugar 9g	**10%**
Protein 16g	**32%**
Vitamin A 21210IU	**424%**
Vitamin C 90.3mg	**109%**
Calcium 164mg	**16%**
Iron 3.7mg	**21%**

* Percent Daily Values are based on a 2000 calorie diet.

- 6 oz. sesame ginger salad dressing

Instructions

1. Preheat oven to 400 degrees.
2. Add quinoa, water, and salt to a rice cooker and cook until fluffy.
3. Combine sweet potato cubes, 2 tablespoons olive oil, ½ teaspoon salt, and ½ teaspoon pepper in a gallon sized Ziplock bag. Toss to combine.
4. Line a large baking sheet with parchment paper and spread sweet potato cubes out in a single layer.
5. Bake in preheated oven for 25-30 minutes, flipping halfway through.
6. While sweet potatoes are baking, combine broccoli florets, ¼ teaspoon salt and 1 tablespoon olive oil in the same gallon sized Ziplock bag. Toss to combine. When the sweet potatoes have 15 minutes left, add broccoli to the pan and return to the 400-degree oven.
7. To serve: fill four bowls with equal amounts of the quinoa, tomatoes, chicken, kale, and roasted vegetables. Serve each quinoa bowl with 2 ounces of the sesame ginger salad dressing or other dressing of choice. Enjoy!

Beef Stir Fry
Servings: 4
Ingredients
- 2 tablespoons vegetable oil divided
- 1 lb. flank steak thinly sliced
- 2 tablespoons cornstarch
- 4 cups mixed vegetables

Sauce
- 3 cloves garlic minced
- 1 teaspoon minced ginger
- 1/3 cup orange juice
- 1/3 cup water
- 1/4 cup low sodium soy sauce
- 3 tablespoons brown sugar
- 1 1/2 teaspoons sesame oil
- 1 tablespoon cornstarch

Instructions
1. Season steak with salt & pepper. Toss with cornstarch and set aside while you prepare the vegetables.
2. Place 1 tablespoon of oil in a pan or wok. Cook the beef in 2 small batches over medium high until browned, about 2-3 minutes (beef does not need to be cooked through). Remove from pan and set aside.
3. Add vegetables to the pan and cook until tender crisp, 4-5 minutes. Remove from pan and set aside with the beef.
4. Combine sauce ingredients except cornstarch in a bowl and stir well.
5. Turn to medium-high and sauce. Bring to a simmer. Combine cornstarch with 3 tablespoons water (or broth) and add it to the boiling sauce a little bit at a time to reach

desired consistency. Let simmer 2 minutes. Add vegetables, beef (and any juices) to the pan and cook until heated through.
6. Serve with noodles or over rice.

NUTRITION INFORMATION
Calories: 423, Fat: 15g, Saturated Fat: 8g, Cholesterol: 68mg, Sodium: 681mg, Potassium: 863mg, Carbohydrates: 43g, Fiber: 7g, Sugar: 10g, Protein: 31g, Vitamin A: 9285%, Vitamin C: 29.9%, Calcium: 84%, Iron: 3.9%

Turkey Lasagna
Makes 8 servings
Ingredients
- 1 (19.5-ounce) package JENNIE-O® Lean Sweet Italian Turkey Sausage
- 1 (26-ounce) spaghetti sauce
- 8 no-boil lasagna noodles
- 1 (15-ounce) container ricotta cheese
- ¼ cup grated Parmesan cheese
- 2 cups shredded mozzarella cheese, divided

Instructions
1. Heat oven to 450ºF. Crumble turkey sausage into a large pre-heated saucepan; discard casings. Cook over medium-high heat 5 to 7 minutes, breaking sausage into chunks and stirring frequently. Always cook turkey to well-done, 165°F as measured by a meat thermometer.
2. Add spaghetti sauce; bring to a boil. Reduce heat; simmer uncovered 5 minutes, stirring occasionally. Place 2 noodles on bottom of 9-inch square baking dish. Spread ¼ of sauce on noodles. Combine ricotta and Parmesan cheese; spoon ⅓ of mixture over sauce. top with ⅓ cup mozzarella cheese. Repeat layering 2 more times and place last 2 noodles on top. Cover with remaining sauce.
3. Cover with foil; bake 25 minutes or until noodles are tender and sauce is bubbly. Uncover; top with remaining 1 cup mozzarella cheese. Return to oven; bake 5 minutes or until cheese is melted. Let stand 5 minutes before serving.

RECIPE NUTRITION INFORMATION
PER SERVING

Calories	420
Protein 31g	
Carbohydrates	38g
Fiber	3g
Sugars	10g
Fat	16g
Cholesterol	65mg
Sodium	780mg
Saturated Fat	6g

Capellini with Chicken, Broccoli, and Pecorino Cheese
Makes: 4 servings
Ingredients
- 1 tablespoon olive oil
- 12 ounces boneless skinless chicken thigh meat, cut into 1-inch pieces
- 3 garlic cloves, grated or minced very fine
- 1 tablespoon fresh (or 1 1/2 teaspoons dried) thyme, minced
- 2 1/2 cups broccoli, cut into 2-inch pieces
- 1/2 cup hot water

- 8 ounces capellini pasta
- 4 tablespoons pecorino cheese, freshly grated
- Salt to taste

Instructions

1. Heat olive oil in a nonstick pan. Add chicken and cook over medium heat 6 to 8 minutes, until lightly browned. Add garlic and thyme and cook 30 seconds more. Remove chicken from pan and keep warm.
2. Add broccoli to pan and sauté for 30 seconds. Add 1/2 cup hot water and cover. Cook about 4 minutes, until broccoli is slightly soft. Bring a large pot of lightly salted water to a boil. Add pasta and cook according to package directions.
3. Add chicken to broccoli and remove pan from heat. When pasta is done, drain and add to pan. Stir and sprinkle with cheese.

Nutrition facts per serving: 415 calories, 30g protein, 53g carbohydrate, 10g fat (2g saturated), 6g fiber

SNACKS

No Bake Oatmeal Energy Balls
yield: 18 (1-INCH) BALLS, APPROX.
Ingredients:
ENERGY BALL BASE:

- 1 1/4 cups Bob's Red Mill Gluten Free Rolled Oats — you can also swap quick oats or a blend of half quick, half old fashioned
- 2 tablespoons "power mix-ins" — chia seeds, flaxseeds, hemp seeds, or additional rolled oats
- 1/2 cup nut butter of choice — peanut butter is my go-to
- 1/3 cup sticky liquid sweetener of choice — honey or maple syrup
- 1 teaspoon pure vanilla extract
- 1/4 teaspoon kosher salt
- 1/2 cup mix-ins — see below for flavor options

CLASSIC CHOCOLATE CHIP:
Any nut butter — honey, 1/2 cup chocolate chips
TRAIL MIX:
Peanut butter — honey, 3 tablespoons chocolate chips, 3 tablespoons chopped peanuts, 2 tablespoons raisins
WHITE CHOCOLATE CRANBERRY:
Almond butter — or cashew butter, honey, 1/4 cup dried cranberries, 1/4 cup white chocolate chips
ALMOND JOY:
Replace 1/2 cup of the oatmeal with 1/2 cup unsweetened coconut flakes — almond butter, any sweetener, 1/4 cup chocolate chips, 1/4 cup chopped almonds
DOUBLE CHOCOLATE:
Any nut butter — any sweetener, 1/2 cup mini chocolate chips, ADD 2 tablespoons cocoa powder
OATMEAL RAISIN COOKIE:

Almond butter — or cashew butter, maple syrup, 1/2 cup raisins, ADD 1/4 teaspoon cinnamon
Instructions

1. Place all of the ingredients in a large mixing bowl: oats, power mix-ins, nut butter, sweetener, vanilla extract, salt, mix-ins, and any other spices you'd like to add. Stir to combine. If the mixture seems too wet, add a bit more oats. If it's too dry, add a bit more nut butter. It should resemble a somewhat sticky dough that holds together when lightly squeezed. Place the bowl in the refrigerator for 30 minutes to set (this will make the balls easier to roll later on).
2. Remove the bowl from the refrigerator and portion the dough into balls of desired size. (I use a cookie scoop to make mine approximately 1 inch in diameter). Enjoy!

RECIPE NOTES
Store leftover energy balls in an airtight container in the refrigerator for up to 2 weeks or freeze for up to 3 months.
For nut allergies: In place of the almond or peanut butter, try sunflower seed butter.
NUTRITION INFORMATION
Amount per serving (1 ball (nutrition info for Classic Chocolate Chip variation)) —
Calories: 123, Fat: 6g, Saturated Fat: 2g, Sodium: 47mg, Carbohydrates: 16g, Fiber: 2g, Sugar: 9g, Protein: 3g

Food suggestions:
-Waffles: Kashi- Calories: 160-200 per 2 waffle serving, Kodiak Cakes toaster waffles- Calories: 220-270 per 2 waffle serving
-Granola: KIND healthy grain clusters-Calories: 250 per 2/3 C serving, Clif Energy Granola- Calories: 250 per 2/3 C serving, Nature Valley-Calories: 200-250 per 1/2 C serving
-Ready-to-drink Fruit Smoothies: NAKED Fruit Smoothies (Blue Machine, Strawberry banana, Berry blast, Mighty mango, Green machine); Simply Smoothies (Strawberry banana, Mango pineapple, Orchard Berry); Bolthouse Farms
Energy Bar suggestions: (These are all just suggestions, if you have another energy bar preference please consult with dietitian.)
-Honey Stinger:

- Energy bars: (Flavors: Peanut Butta, Cherry Almond, Coconut Almond, Mint Almond) Calories: 180-200
- Cracker N' Nut butter filled (Flavors: PB Milk Chocolate, Almond Butter Dark Chocolate, Cashew Butter Milk Chocolate): Calories: 220
- Waffles (Flavors: Honey, Vanilla, Chocolate, Caramel, Strawberry, Gingersnap, Lemon, Vanilla Chocolate, Chocolate Mint, Salted Caramel, Cinnamon, Wildflower Honey): Calories: 140

-Power Bar Performance Energy Bars: (Flavors: Peanut Butter, Chocolate, Vanilla Crisp): Calories: 230
-Clif

- Energy bars: Any flavor-Calories: 250
- Nut butter filled or Fruit smoothie filled: Any flavor-Calories: 220-230

-KIND

- Breakfast bars: Any Flavor- Calories: 220

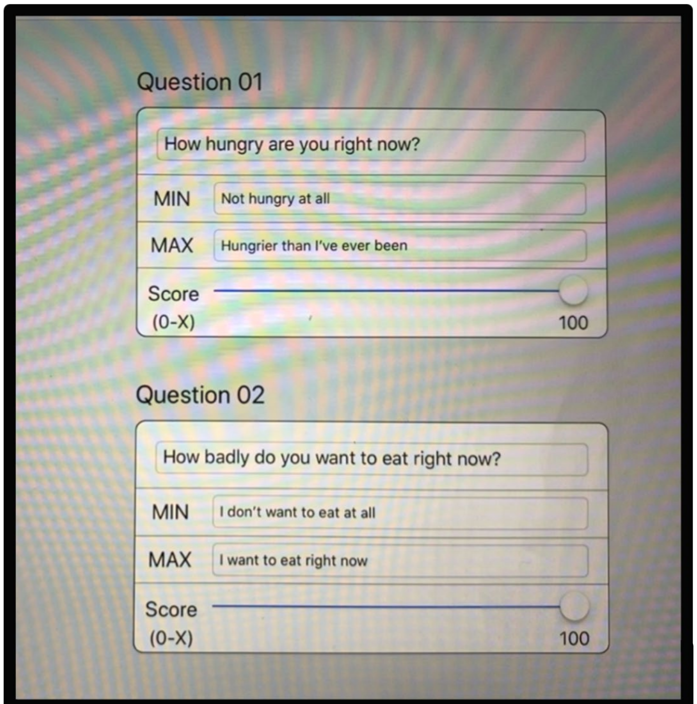
- Healthy Grains bars: (Flavors: Dark Chocolate Chunk, Oats & Honey with toasted coconut, Peanut butter dark chocolate, double dark chocolate, vanilla blueberry, cinnamon oat, almond butter dark chocolate): Calories: 150
- Nut Butter Filled: (Flavors: Chocolate PB, Honey Almond Butter): Calories: 170
- Protein bars: (Flavors: Almond Butter Dark Chocolate, Double Dark Chocolate, Toasted Caramel Nut, Crunchy Peanut Butter, White Chocolate Cinnamon Almond): Calories: 250
- Simple crunch: (Flavors: Peanut Butter, Oats & Honey, Dark Chocolate): Calories: 180

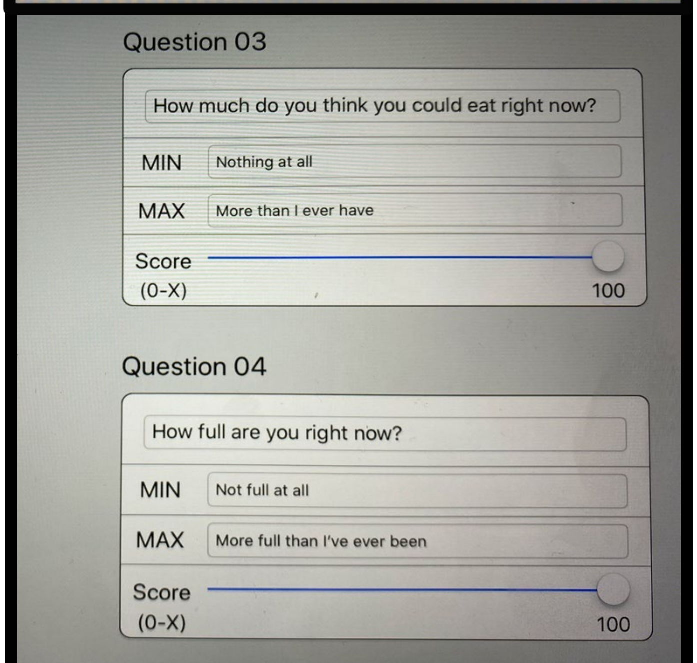
-Quaker:

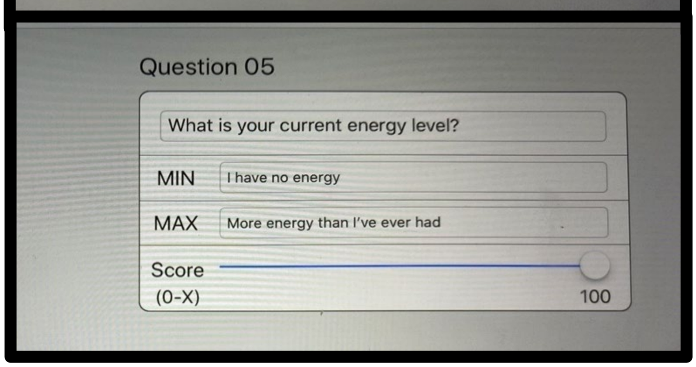
- Oatmeal to Go
- Chewy

***Always lean towards products with more carbs than fat!

APPENDIX C


Question 01
How hungry are you right now?
MIN
Not hungry at all
MAX
Hungrier than I've ever been
Score
(0-X)
100
Question 02
How badly do you want to eat right now?
MIN
I don't want to eat at all
MAX
I want to eat right now
Score
(0-X)
100


Question 03
How much do you think you could eat right now?
MIN
Nothing at all
MAX
More than I ever have
Score
(0-X)
100
Question 04
How full are you right now?
MIN
Not full at all
MAX
More full than I've ever been
Score
(0-X)
100


Question 05
What is your current energy level?
MIN
I have no energy
MAX
More energy than I've ever had
Score
(0-X)
100